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USE OF LAN (LOCAL AREA NETWORK) TECHNOLOGY IN DSCS
(DEFENSE SATELLITE COM. (U) STANFORD TELECOMMUNICATIONS
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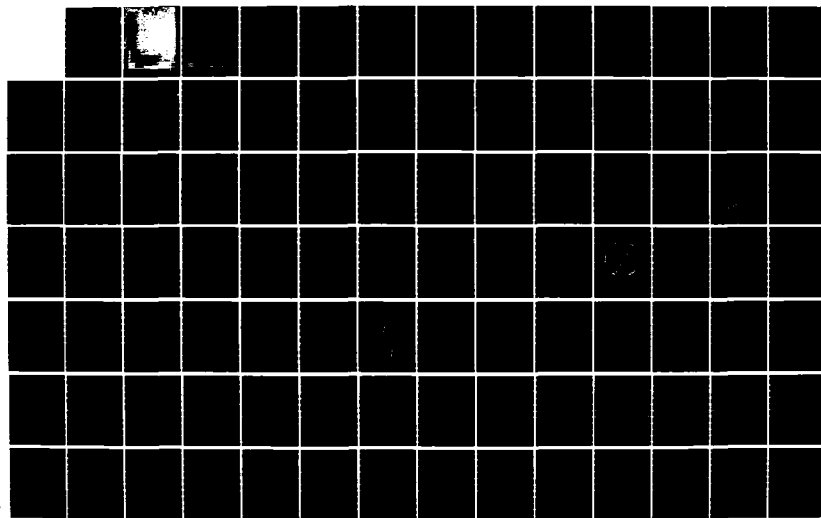
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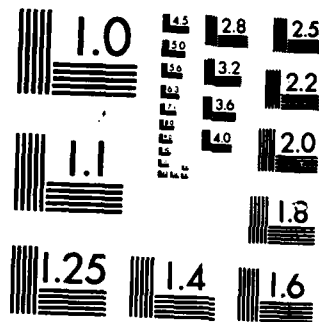
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USE OF LAN TECHNOLOGY IN
DSCS EARTH TERMINALS

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CONTRACT NO: DCA 100-85-C-0062
TASK NO: 85-3

FINAL REPORT
(OCTOBER 1985 - FEBRUARY 1986)

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SECURITY CLASSIFICATION OF THIS PAGE

AD-A165496

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS NONE	
2a. SECURITY CLASSIFICATION AUTHORITY N/A		3. DISTRIBUTION/AVAILABILITY OF REPORT UNLIMITED	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) STI/E-TR850156		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION Stanford Telecommunications, Inc.	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Defense Communications Engineering Center	
6c. ADDRESS (City, State and ZIP Code) 6888 Elm Street McLean, VA 22101		7b. ADDRESS (City, State and ZIP Code) 1860 Wiehle Avenue Reston, VA 22090	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Defense Communications Agency	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DCA100-85-C-0062	
8c. ADDRESS (City, State and ZIP Code) Contract Management Division, Code 680 Washington, D.C. 20305-2000		10. SOURCE OF FUNDING NOS.	
		PROGRAM ELEMENT NO. 33126K	PROJECT NO. B754
11. TITLE (Include Security Classification) Use of LAN Technology in DSCS Earth Terminals (U)			
12. PERSONAL AUTHOR(S) Alan Jacobsen, Matthew Griffin			
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM Oct 85 to Feb 86	14. DATE OF REPORT (Yr., Mo., Day) 86, 2, 28	15. PAGE COUNT 211
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Local Area Networks; Earth Terminals Defense Satellite Communication System (DSCS)	
FIELD	GROUP		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
The report addresses the use of local area network (LAN) technology to support intercommunications within the Defense Satellite Communications System (DSCS) earth terminals. A summary of local area network capabilities and options is provided as background material. Two types of device intercommunications are identified: the intercommunication of equipment to directly provide the circuit-switched channels needed for DSCS user circuits and the intercommunication of equipment in support of control and status monitoring functions. Issues and concerns regarding the application of LAN technology to either of these objectives are discussed. Additionally, the application of digital switching technology---specifically, use of the Integrated Multiplex, Patch, and Test (IMPAT) equipment---has also been considered as a means to fulfill these intercommunication requirements.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL John Knab		22b. TELEPHONE NUMBER (Include Area Code) (703) 437-2058	22c. OFFICE SYMBOL DCEC

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SECTION 1

INTRODUCTION & EXECUTIVE SUMMARY

1.1 BACKGROUND

Satellite communications as provided by the Defense Satellite Communications System (DSCS) have become an integral part of the Defense Communications System. In providing a network of satellite-linked circuits, DSCS supports a variety of users and user data rates ranging from 75 bps (TTY) to wideband data requirements as high as 10 Mbps. Composed of terminal, space, and control segments, DSCS has now entered Phase III of its evolution with the launch of the first DSCS III satellite in October 1982.

The continued evolution of the Defense Satellite Communications System (DSCS) involves the further development and deployment of earth terminals and their associated equipment. Elements of the terminal segment include:

- the Technical Control Facility, providing the user interface to DSCS and any necessary signal conditioning equipment;
- the Digital Communications Subsystem (DCSS), encompassing the modulation, multiplex, coding, and processing equipment needed to assemble the various types of supported user data into a digital format suitable for transmission through the DSCS satellite network;
- the Interconnect Facility (ICF), linking the TCF and DCSS equipment when they are physically separated at a particular installation; and
- the Link Terminal (LT), providing the RF subsystems interfacing between the DCSS at 70/700 MHz IF and the DSCS space segment.

DSCS earth terminals incorporate or will incorporate subsystems and equipment such as the DSCS Electronic Counter-Counter Measures Control Subsystem (DECS), the DSCS Frequency Division Multiple Access (FDMA) Control Subsystem (DFCS), the Integrated Multiplex, Patch and Test (IMPAT) equipment, etc. While the DSCS ground segment is currently defined by groupings of such subsystems and equipment, the groupings are not standardized---each DSCS terminal is typically configured uniquely.

Generically, the terminal equipment can be seen in terms of the equipment groups of Figure 1-1. In the forward direction, user signals to be transmitted, after any needed conditioning performed by the Technical Control Facility, are routed through a Main Distribution Frame to multiplexers and further signal conditioning equipment (encryptors, A/D converters, etc.) as required. The employed multiplexing schemes are coordinated network-wide, thereby establishing the desired user circuits. After multiplexing, the signals are routed to the modems and up-converters which define the various DSCS satellite channels. User signals received at the earth terminal follow a similar procedure in the reverse direction. Interconnection of the terminal equipment, then, defines the equipment chains needed to support the user circuits.

Figure 1-1 also indicates the capability of monitoring and controlling terminal equipment. Many of the existing or planned subsystems incorporate control and status monitoring functions. Future terminals, however, may involve an integrated approach to control and status monitoring, thereby requiring further intercommunication between terminal devices. One such integrated terminal currently envisioned for future deployment is the Modularized Integrated Satellite Terminal (MIST), a light terminal intended to support a maximum user data throughput of 10 Mbps.

Currently, a terminal's complement of equipment is arranged by modular racks. The Digital Communications Subsystem (DCSS) defines 22 different rack configurations, each rack provided with a specific equipment set. For

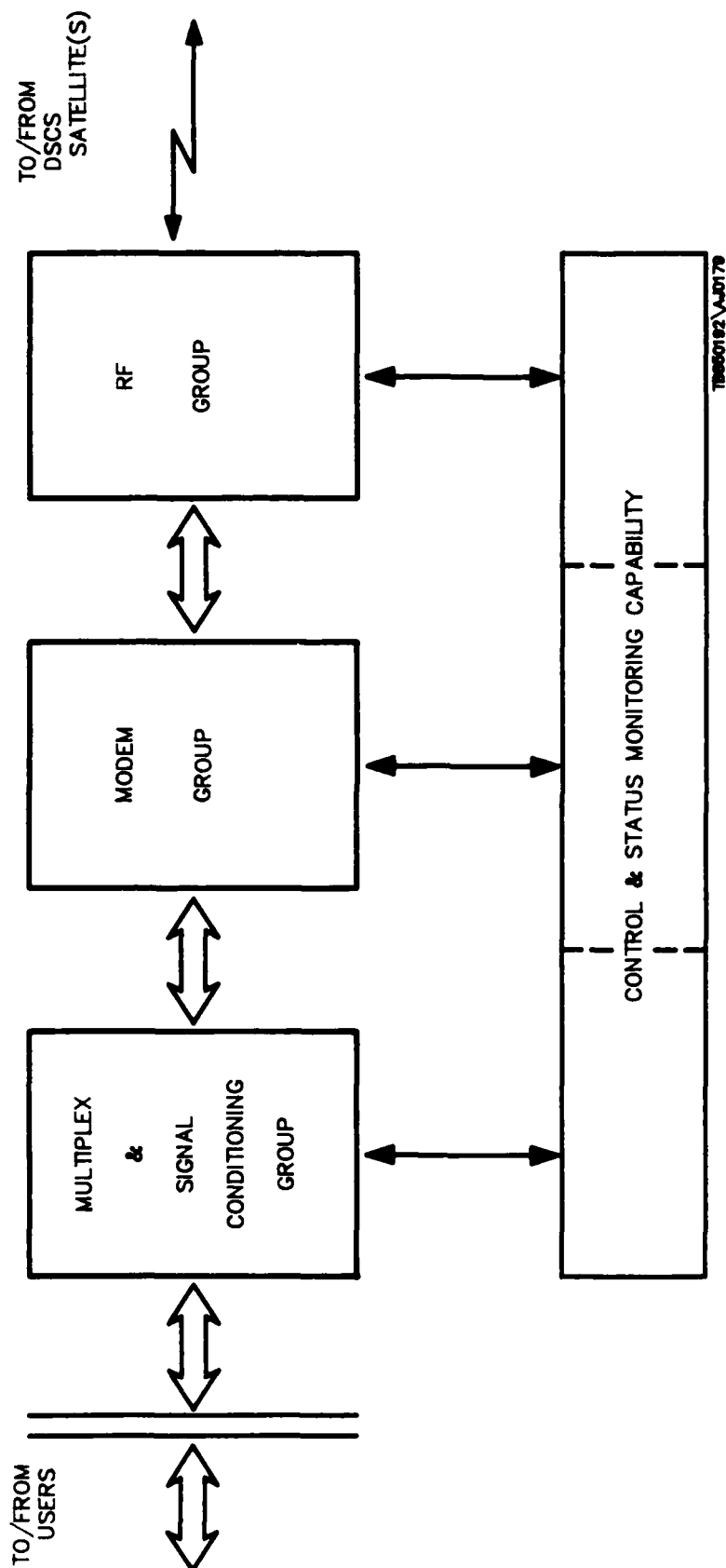


FIGURE 1-1: DSCS TERMINAL EQUIPMENT

a particular earth terminal's communications requirements, the necessary racks (including those needed to provide a measure of equipment redundancy) are installed and interconnected according to the desired terminal configuration. Connections are generally made through the top of the rack and/or through associated patch panels. Note that equipment failures or routine maintenance generally lead to changes in equipment connections more frequently than do those changes required for network or terminal reconfigurations.

The current rack-based modularity, however, has its disadvantages. Often, an entire rack of equipment stands idle due to the failure of only one of its components. Furthermore, the wiring of the rack assembly does not readily allow the replacement of equipment with other than the same component. As DSCS earth terminal designs evolve, however, the ability to replace single components or subsystems rather than full equipment racks becomes more desirable. This goal would be well served if it were possible to standardize all rack assemblies so that any piece of equipment could be installed into the rack. The problem would then be to establish the necessary interconnections between equipment.

1.2 OBJECTIVES

The interconnection of DSCS terminal equipment in support of terminal integration is the subject of this study. With the recent advent of inexpensive distributed computing power, the interconnection of different information processing devices has become more and more important. In office and industrial environments, the desired intercommunication between devices is now often achieved through local area networks. A local area network (LAN) efficiently provides the needed connectivity between devices by allowing all units to share a common transmission medium and/or central device. The applicability of local area networks to accomplish the interconnection of DSCS subsystems is one focus of this report. Additionally, the use of digital matrix switching technology---specifically, use of the IMPAT---as a means to interconnect terminal equipment is considered.

This study, then, serves to assess the use of local area networks and, to some extent, digital matrix switching in DSCS earth terminals. A fundamental understanding of the capabilities of local area networks is provided as part of this work in order to allow the reader to make an informed assessment of the presented material. The two main thrusts of this report concern the type of earth terminal intercommunications to be supported by local area networks: the interconnection of equipment in support of DSCS user circuits and/or the interconnection of equipment in support of the flow of equipment control and status signals.

The report is organized in the following manner:

- Section 1 provides an introduction and executive summary;
- Section 2 identifies the two identified communications problems and places the interconnection of terminal devices in the context of a layered network architecture;

- Section 3 reviews the subsystems composing the DSCS earth terminals;
- Section 4 provides an introduction to local area network technology;
- Section 5 specifically addresses the application of LAN technology to the two identified intercommunication roles;
- Section 6 considers the use of IMPAT in fulfilling the intercommunication needs;
- Appendix A documents specific DSCS equipment types and their interfaces;
- Appendix B provides a listing of commercially available LAN products; and,
- Appendix C estimates the throughput requirements for baseline light, medium, and heavy terminals.

The objectives of this report are thus to identify and explore issues concerning the use of local area network technology in the DSCS earth terminals. The goals of any such application are reduced implementation costs, enhanced system modularity, and the potential to reconfigure and/or expand the terminal interconnections. Any proposed solution, however, must additionally be considered in terms of space conservation, reliability, maintainability, communications security, system complexity, and transparency from the point of view of the DSCS user community.

APPLICATION OF LAN TECHNOLOGY: GOALS

- REDUCED TERMINAL IMPLEMENTATION COSTS
- ENHANCED MODULARITY AND FLEXIBILITY
- EXPANDABILITY

APPLICATION OF LAN TECHNOLOGY: ISSUES

- COST
- SPACE CONSERVATION
- RELIABILITY
- MAINTAINABILITY
- COMMUNICATIONS SECURITY
- SYSTEM COMPLEXITY
- NETWORK PERFORMANCE; E.G., DELAY VS. THROUGHPUT

1.3 EXECUTIVE SUMMARY

This study addresses the use of local area network (LAN) technology in the DSCS earth terminals, indicating issues and considerations pertinent to such an application. This assessment of LAN technology complements the ongoing effort to develop an integrated earth terminal design which would allow the modular deployment of DSCS equipment and subsystems and would operate under either central or distributed command. Use of LAN technology would support intercommunications among devices and thereby provide the means to support full system/subsystem integration of the DSCS earth terminals.

Problem Definition

Two types of device intercommunication may be identified: the intercommunication of equipment to directly provide the channels needed for DSCS user circuits and the intercommunication of equipment in support of control and status monitoring functions. Intercommunications in support of DSCS user circuits must provide dedicated channels for both voice and data circuits, the data circuits spanning a wide range of data rates. In addition, the interconnection of devices must provide flexibility and allow re-routing of signal flows in the event of equipment failure or DSCS network and/or terminal configuration changes. Intercommunications in support of control and status monitoring functions, on the other hand, are not subject to as stringent requirements, allowing considerably more latitude in the type of LAN that may be employed.

Communications networks are generally seen in terms of the switching technique employed by the network. Circuit, message, and packet switching are well-known designations for switching types. While local area networks typically support computer-to-computer communications by providing packet-switched communications, the DSCS network provides circuit-switched services to its users. If local area networks are to be used for the intercommunication of terminal equipment in support of DSCS user circuits,

PROBLEM DEFINITION

- DSCS SUBSYSTEM INTEGRATION REQUIREMENTS
 - INTERCOMMUNICATIONS BETWEEN DEVICES TO SUPPORT DSCS USER SERVICES
 - DEDICATED CHANNELS
 - VARIETY OF USER RATES
 - REROUTING FOR FAILOVER, NETWORK AND TERMINAL RECONFIRMATION
 - INTERCOMMUNICATIONS BETWEEN DEVICES FOR EQUIPMENT CONTROL AND STATUS MONITORING
- POSSIBLE SWITCHING TECHNIQUES
 - CIRCUIT - END-TO-END CONNECTIVITY (DSCS)
 - MESSAGE - COMPLETE DIGITAL MESSAGES
 - PACKET - DIVISION OF MESSAGES INTO PACKETS YIELDS NON EFFICIENT USE OF CHANNEL (MUST LOCAL AREA NETWORKS)
- LAYERED NETWORK ARCHITECTURES ESTABLISH THE FRAMEWORK FOR DEVICE INTERCOMMUNICATION PROTOCOLS
- DSCS COMPRISES A NETWORK OF RELAY SYSTEMS CONNECTING ENDORSERS IN A USER TRANSPARENT FASHION.

then the local area network must possess circuit-switched capabilities. The intercommunication of control and status signals, by contrast, is not restricted to any particular switching technique.

The interconnection between devices anticipated for DSCS earth terminal integration requires some common basis for meaningful communication, especially in regard to the intercommunication of control and status signals. Layered network architectures have been developed to provide a logical and hierarchical division of responsibilities in support of device intercommunications. For example, the Open Systems Interconnection (OSI) Reference Model, established by the International Organization for Standardization (ISO), defines a seven-layer architecture (illustrated in Figure 1-2) demarcating the responsibilities required in the intercommunications between systems. The establishment and use of standardized protocols to fulfill the requirements of each layer will ultimately permit disparate devices to communicate with one another. In developing standards for local area networks, the IEEE 802 committee has closely paralleled the OSI architecture in order to define the standard operations and characteristics which 802 local area networks must exhibit.

Such a layered architecture naturally leads to local area networks which operate transparently, invisible to the LAN users. This transparency is essential if LAN technology is to be used to interconnect devices in support of DSCS user circuits. The concept of a layered network architecture is important too in the intercommunication of DSCS equipment control and status signals---above the layers of communication responsibility provided by the local area network, there must be established mechanisms by which different equipment types may signal and respond to one another. Merely providing the means of intercommunication by employing a local area network does not guarantee that communicated signals will be correctly interpreted. This issue is critical to the design of an integrated DSCS earth terminal, although not wholly within the scope of this study---many of the equipment types to be interconnected via a LAN are "dumb" devices, not possessing the processing capabilities often

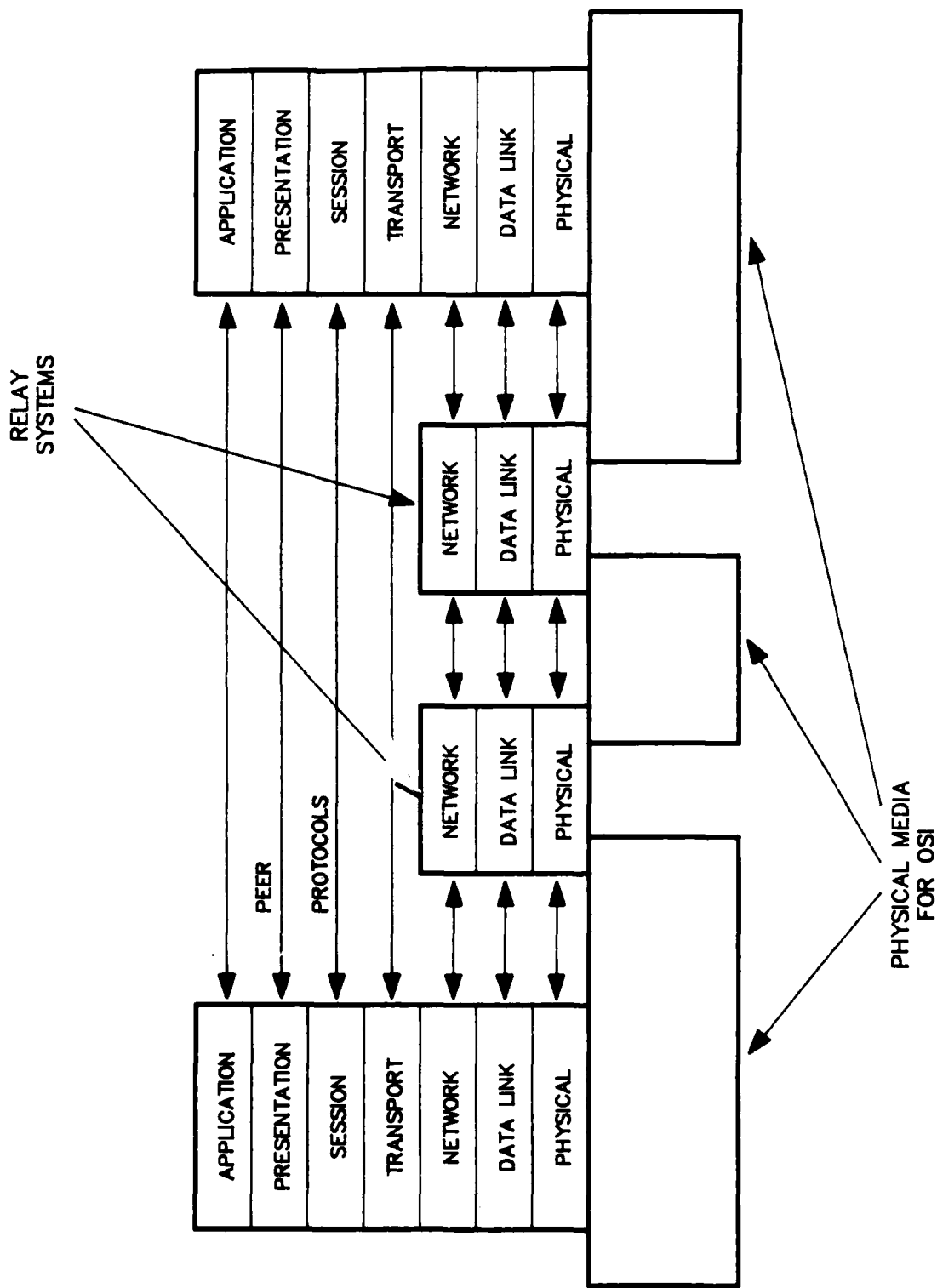


FIGURE I-2: THE OSI REFERENCE MODEL ARCHITECTURE
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assumed in local area networks. Nonetheless, the network interface units used to connect terminal equipment to the LAN may possibly assume some higher layer responsibilities and thereby compensate for any deficiencies in processing power.

DSCS Earth Terminal Definition

To understand the intercommunications requirements which a LAN must fulfill, the physical and operational characteristics of DSCS terminal equipment and subsystems have been studied. From study of the DSCS Program Plan and Transition and Integration Plan, baseline earth terminals have been defined in order to provide representative examples of terminal equipment complements.

The interaction within the earth terminal of currently existing subsystems acts to define much of the terminal intercommunications requirements. For example, the Digital Communication Subsystem (DCSS) encompasses all terminal baseband equipment which, if a LAN is to support DSCS user circuits, must be interconnected. Similarly, the DSCS ECCM Control Subsystem (DECS) provides control and monitoring capabilities for its associated equipment; a LAN might possibly be used to support the communication of control and status between DECS equipment and the DECS processor.

Four distinct terminal configurations are possible in DSCS earth terminals, imposing a variety of intercommunication requirements and affecting the design of any local area network. For example, in some terminals, equipment of the DCSS is split between separate Technical Control Facility (TCF) and Earth Terminal (ET) installations, requiring some means of interconnection. While this interconnection is currently handled by the Interconnect Facility, use of LAN technology may usurp that role.

Typical equipment connectivities within the terminals have been identified to characterize equipment-to-equipment communications in support of user

DSCS TERMINAL DEFINITION

- DSCS SUBSYSTEMS
 - DIGITAL COMMUNICATIONS SUBSYSTEM (DCSS)
 - DSCS OPERATIONAL CONTROL SYSTEM (DOCS)
 - DSCS FDMA CONTROL SYSTEM (DFCS)
 - DSCS ECCM CONTROL SYSTEM (DECS)
 - DSCS OPERATIONAL SUPPORT SYSTEM (DOSS)
 - RF SUBSYSTEMS (SAMT PROVIDES CENTRAL TERMINAL CONTROL FACILITY)
- TERMINAL SITE CONFIGURATIONS INTEGRATION REQUIREMENTS
- TYPICAL EQUIPMENT CONNECTIVITIES
 - EQUIPMENT TO EQUIPMENT COMMUNICATION TO SUPPORT USER CIRCUITS
 - CONTROL AND STATUS SIGNALS FROM EQUIPMENT TO CONTROL PROCESSOR(S)
- REPRESENTATIVE BASELINE TERMINALS DEFINED TO EVALUATE SUBSYSTEM INTERCOMMUNICATION SOLUTIONS
 - LIGHT TERMINAL: 6 MBPS AGGREGATE USER DATA RATE
 - MEDIUM TERMINAL: 12 MBPS
 - HEAVY TERMINAL: 37 MBPS

circuits and equipment-to- processor communications in support of terminal control and status monitoring functions. Based on these connectivities and the available terminal data, three representative baseline terminals have been defined which reflect light, medium, and heavy (with respect to overall throughput) terminals. These models are then used to evaluate possible intercommunication solutions.

Local Area Network Options

An understanding of the capabilities of local area networks is necessary to assess the application of LAN technology in support of the identified two types of DSCS terminal intercommunications. Although often associated with computer communications within an office, local area networks can be broadly defined as the intercommunication of communicating devices within a limited physical region. The wide range of LAN implementation possibilities has led to a need for standardization. The IEEE 802 committee and the U.S. Air Force, for example, have both defined standards for device intercommunication in an attempt to standardize local area network interfaces among LAN vendors.

The choice of LAN topology, transmission media, and access control technique are options available for any given application. As depicted by Figure 1-3, bus, ring, star, tree, or hybrid topologies are possible, implemented using either twisted wire pair, coaxial cable, fiber-optic cable, or unbounded transmission media or a mixture of media types. The choice of topology might be based on some existing hierarchy among the devices to be attached or reflect reliability considerations. Similarly, the media chosen is typically a function of the bandwidth required for the application and cost and performance considerations.

Related to the choice of topology and transmission media, the local area network's access control technique governs the access of connected devices to the communications channel. The control strategy may, in most cases, be implemented in either centralized or distributed manner, but reliability in

LOCAL AREA NETWORK OPTIONS

- CURRENT EFFORTS AT STANDARDIZATION
 - IEEE 802 COMMITTEE
 - USAF UNIFIED LOCAL AREA NETWORK ARCHITECTURE (ULANA)
- TOPOLOGIES
 - BUS
 - STAR
 - RING
 - TREE
 - HYBRID
- TRANSMISSION MEDIA: BANDWIDTHS, COST
 - TWISTED PAIR
 - COAXIAL CABLE
 - FIBER-OPTIC CABLE
 - UNBOUNDED MEDIA
- ACCESS CONTROL TECHNIQUES: CENTRALIZED VS. DISTRIBUTED
 - RESERVATION
 - SELECTION
 - RANDOM ACCESS
- ACCESS PROTOCOL PERFORMANCE
 - THROUGHPUT
 - DELAY
 - OTHER INDICATORS

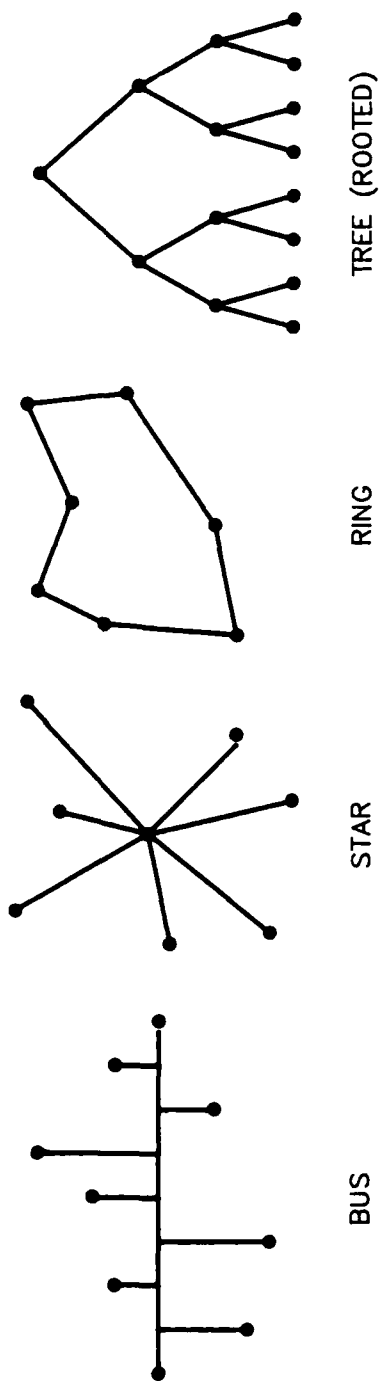
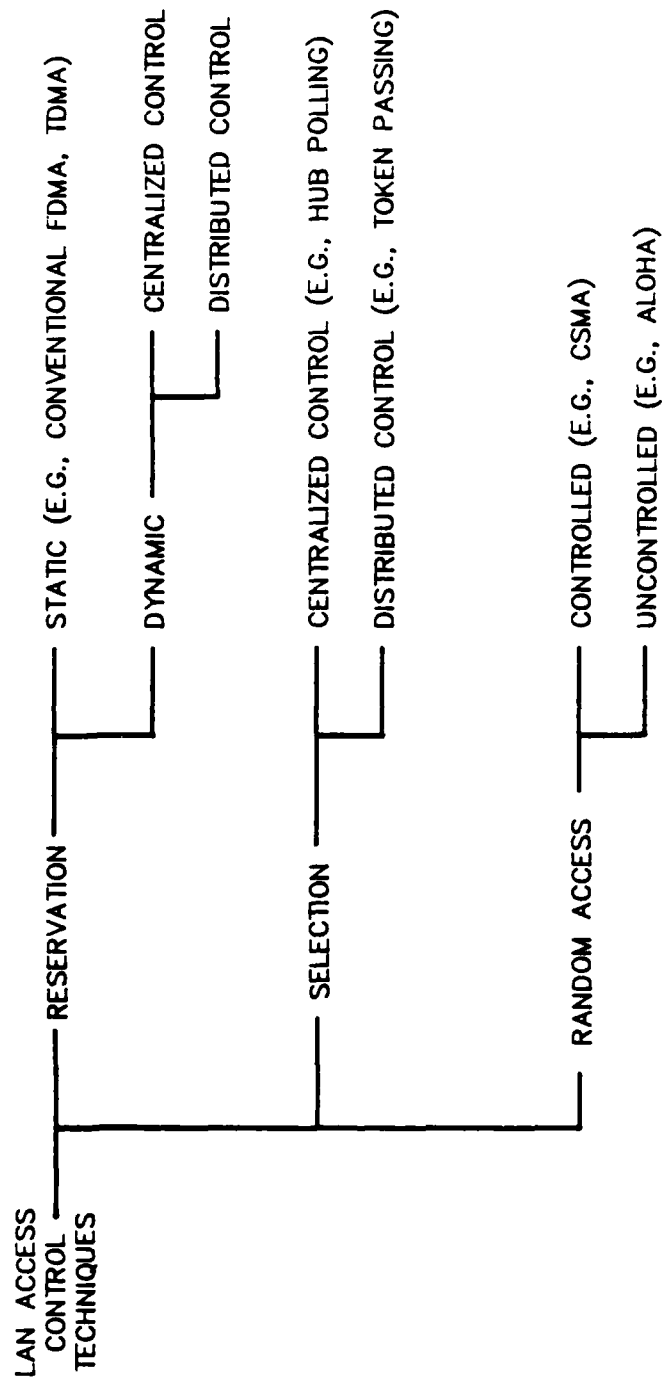


FIGURE 1-3: LAN TOPOLOGIES
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LOCAL AREA NETWORK ACCESS CONTROL TECHNIQUES



local area networks is generally enhanced if network control is distributed. Three types of access protocols may be identified:

- reservation techniques, which effectively reserve channel capacity for users of the local area network;
- selection techniques, in which users are in some way signalled and thus granted channel access; and,
- random access techniques, which attempt to provide channel access to users upon demand.

Performance capabilities of a local area network are often seen in terms of the performance of the access control technique, assessing how well the access protocol can provide service to the users of the local network. Such performance is typically seen as a function of the network traffic load and is quantified in terms of the network throughput or, since most LAN's support packet-switched communications, the delay incurred in the transmission of a packet. Other performance indicators are of course available, but throughput and delay are generally considered the most critical measures. The differences among the three access techniques identified above may be discussed in terms of throughput and delay: while random access techniques generally provide low packet delays for low throughput, they tend to exhibit ever-increasing delays at the highest throughput levels; by comparison, selection and reservation schemes typically provide finite delays at high throughput but suffer some delay overhead at the lowest throughput levels.

Application of LAN Technology

On the basis of current LAN technology and the assessment of DSCS earth terminal communications requirements, issues and concerns regarding the use of local area networks in the DSCS earth terminals have been exposed. As noted, the interconnection of DSCS terminal equipment involves two types of intercommunications---in support of DSCS user communications and in support of the relay of control and status signals. Two distinct applications of

APPLICATION OF LAN TECHNOLOGY

- TWO DISTINCT APPLICATIONS
 - FULL INTERCOMMUNICATIONS LAN TO SUPPORT DEVICE INTERCOMMUNICATIONS FOR BOTH DSCS USER CIRCUITS AND EQUIPMENT CONTROL & STATUS SIGNALS
 - CONTROL AND STATUS CAN TO SUPPORT INTERCOMMUNICATION OF EQUIPMENT CONTROL & STATUS SIGNALS ONLY
- FULL INTERCOMMUNICATIONS LAN
 - BROADBAND BUS PROVIDING DEDICATED CHANNELS
 - REPRESENTATIVE DESIGN EXAMPLE ILLUSTRATES:
 - NETWORK INTERFACE UNITS
 - LAN MANAGEMENT
 - RELIABILITY AND COST
- CONTROL AND STATUS LAN
 - MAY ALLOW PACKET-SWITCHING TECHNIQUES AND USE OF COMMERCIALY AVAILABLE EQUIPMENT
 - TWO CONNECTIVITY STRATEGIES
 - CONNECTION OF ALL EQUIPMENT
 - CONNECTION OF PROCESSORS ONLY
 - LAN DESIGN INTERDEPENDENT WITH INTEGRATED CONTROL AND STATUS MONITORING CONCEPT

LAN technology have therefore been considered: first, a full intercommunications LAN in support of both types of intercommunications, and, second, a control and status LAN in support of equipment control and status signals only.

Full Intercommunications LAN

A full intercommunications LAN, in addition to supporting the communication of control and status signals, must provide reliable circuit-switched communications (both analog and digital) between terminal equipment in support of DSCS user services. A full intercommunications LAN must consequently employ a reservation access control technique in order to establish the needed dedicated channels. In the interests of reliability, the access control technique should be implemented in a distributed fashion to avoid the possibility of single-point failure. Dedicated channels must be provided between each equipment input and output pair composing the DSCS user circuits' equipment chains and for all associated redundant equipment; the data rate which the local area network must support is thus greater than the aggregate user data rate of the terminal. Bandwidth requirements, then, indicate that fiber-optic cable, broadband coaxial cable, or unbounded transmission media must be employed. Unbounded media (radio frequency or infrared), however, either pose interference difficulties or involve immature technologies and hence are here judged inapplicable. Finally, reliability considerations lead to the choice of a bus topology for the full intercommunications LAN---while other LAN topologies may be employed, a bus is seen as most appropriate.

Representative Design. Given this generic understanding of what a full intercommunications LAN should be like, a representative design concept is presented which is similar to the Shipboard Communications Area Network (SCAN) currently under development by the Department of the Navy. This example---a frequency division multiple access (FDMA) broadband coaxial bus local area network---aids in revealing aspects of a full intercommunications LAN which must be considered no matter what specific design is developed.

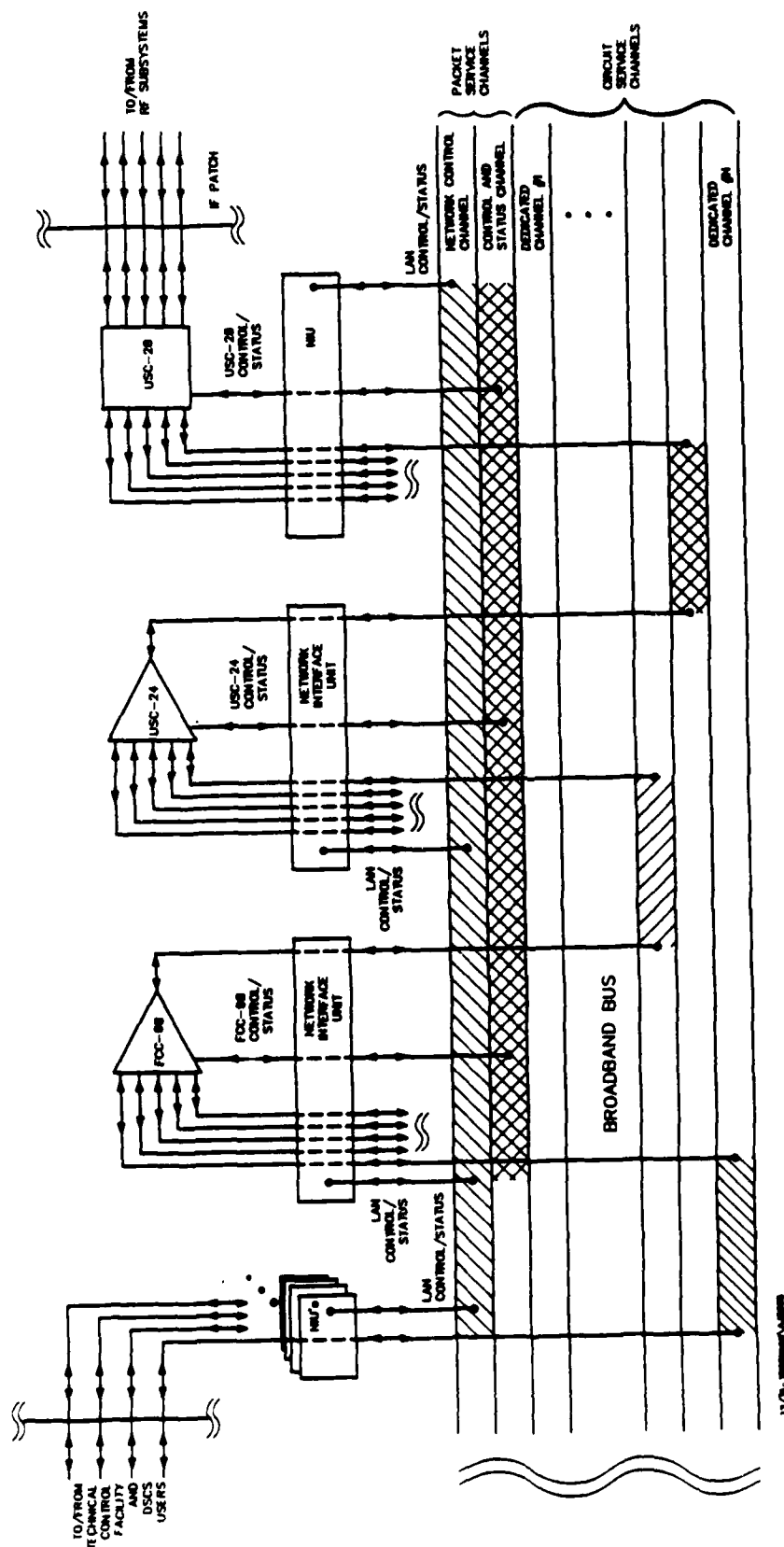


FIGURE 1-4: REPRESENTATIVE USE OF FULL INTERCOMMUNICATIONS LAN

By using frequency division multiple access as the reservation access control technique, dedicated frequency channels between equipment input and output pairs are provided in support of DSCS user circuits. Although dedicated FDM channels might also be used for the intercommunication of control and status signals, more efficient use of channel capacity is realized if one or more channels are shared by the attached devices through selection or random access packet-switching techniques. Control of the local area network itself is presumed to be regulated via such a packet-switched FDM channel. Figure 1- 4 provides an overview of the concept.

Network Interface Units. Associated with each device connected to the full intercommunications LAN is a network interface unit (NIU). Generically, network interface units provide the interface between a local area network and the attached device, implementing the lowest functional levels of a layered network architecture. As an example of a possible implementation, the network interface units for the representative design of a DSCS earth terminal full intercommunications LAN are conceived here as modular units composed of four module types:

- Fixed-frequency cable driver modules to output equipment signals to the LAN;
- Frequency-agile cable receiver modules capable of accepting signals from the LAN and, upon command, switching from one frequency channel to another;
- Packet service modules to input and output communications on the shared packet service channel(s) and, with its associated microprocessor, respond to LAN commands governing network operations; and,
- Input/output modules to serve as interfaces between the NIU modules and each of the various attached device types.

An NIU for a particular piece of terminal equipment would then be assembled from the appropriate modules: a cable driver module for each equipment output, a cable receiver module for each input, a packet service module for the equipment control and status ports, and appropriate input/output modules. The concept of an input/output module is essential to any application of LAN technology in the DSCS earth terminals---terminal equipment and subsystems currently deployed have not been designed for interconnection via a LAN, and the control and status interfaces in particular do not respect any one standard. The I/O module is meant to present a standard interface to the other NIU modules but a custom interface to its associated device. Indeed, if desired, the I/O module might be used to provide remote control and status capabilities for a particular piece of equipment by assuming the front panel functions. It is in this sense, then, that higher layers of a layered network architecture may involve LAN technology.

Other Issues. Issues associated with a full intercommunications LAN include LAN management, the handling of classified and unclassified data, access to the LAN, and the impact of terminal configurations. These issues are explored in the report, revealing considerations that must be addressed in the implementation of a full intercommunications LAN.

LAN management, for example, involves the development of a management subsystem to direct the network interface units, especially in switching among frequency channels of the broadband bus. In this way the LAN provides configuration control of the DSCS earth terminal. Ideally, the LAN management subsystem would provide a user-friendly interface, advising the operator of correct and incorrect connections, failure points, and the end-to-end equipment connectivities. Such a capability promotes the error-free set-up of DSCS user circuits and reduces reliance on operator judgement.

Reliability and Cost. Finally, reliability and cost concerns are discussed. The network interface units represent the major factors in both reliability and cost, especially if new product development is required. Given the intercommunications requirements and currently available LAN products, a full intercommunications LAN for the DSCS earth terminals will require significant development effort, although some use of existing products may be possible. Reliability of the local area network can be established through various design approaches, allowing communications failures to be effectively limited to the individual connections provided by the NIU's. Failure of an NIU will eliminate the associated attached device from the LAN, disrupting that DSCS user circuit, but such failure may be treated as equivalent to the failure of the device itself--- re-configuration of the LAN connectivities to introduce redundant equipment will restore the circuit while repairs are made.

The costs of a full intercommunications LAN per terminal will be fairly high, on the order of \$500,000 to \$7 million depending on the terminal size and on the interconnections to be supported by the LAN. These figures are estimated by looking at the interconnection requirements and assuming that each NIU module costs \$1500, not including development costs. Development costs will be incurred since the capabilities necessary for a full intercommunications LAN are not presently commercially available. Since the technology involved is not particularly advanced, however, development costs should range between \$100,000 and \$500,000 for each module.

Control and Status LAN

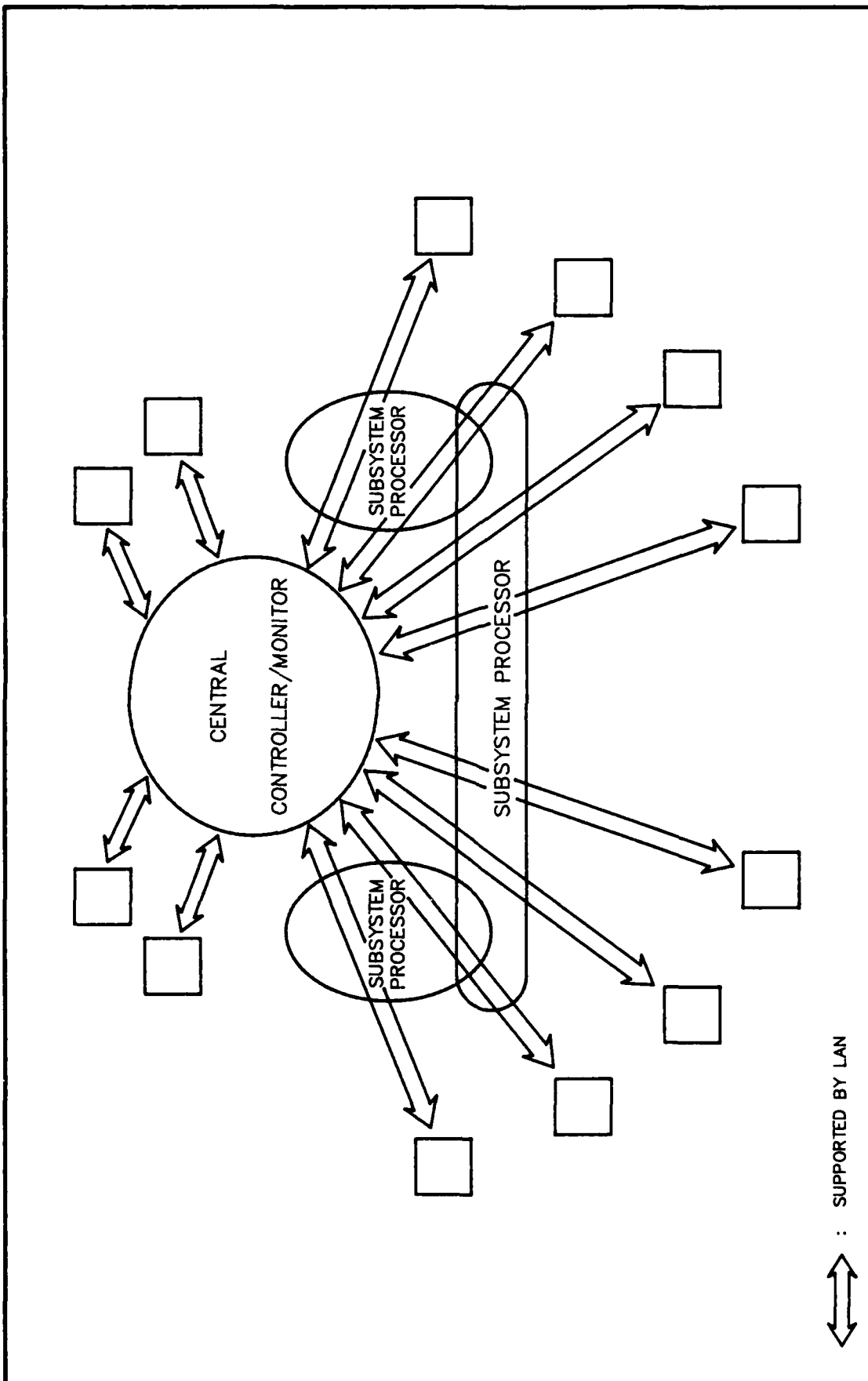
A different, more limited application of LAN technology in the DSCS earth terminals is possible, supporting only the control and status monitoring functions as required for DSCS subsystem integration---interconnection of devices in support of DSCS user circuits would not be supported by such a control and status LAN. A control and status LAN would support the communication of control and status signals between DSCS terminal equipment and the associated controlling and monitoring processors. The bursty

nature of this type of communications and the relatively low data rates involved much better suit the technology currently provided by commercially available local area networks than do the requirements of a full intercommunications LAN. Cost-efficient applications of LAN technology to realize a control and status LAN may thus be feasible using off-the-shelf components.

The specific implementation of a control and status LAN, however, depends on the envisioned operation of earth terminal control and monitoring functions and the equipment-to-processor connectivity desired. Some existing terminal devices currently communicate control and status signals with their respective subsystem processors---the processor-to-equipment channel typically being a direct cable link. Other devices may not currently possess remote control and status capabilities or may possess such capabilities yet not currently be associated with a controlling/monitoring processor. At the same time, some future DSCS earth terminal designs---in particular, the Modularized Integrated Satellite Terminal (MIST)---conceptualize the presence of a central processor governing operation of the terminal and its equipment. The exact workings of such a centralized processor, however, have not yet been specified.

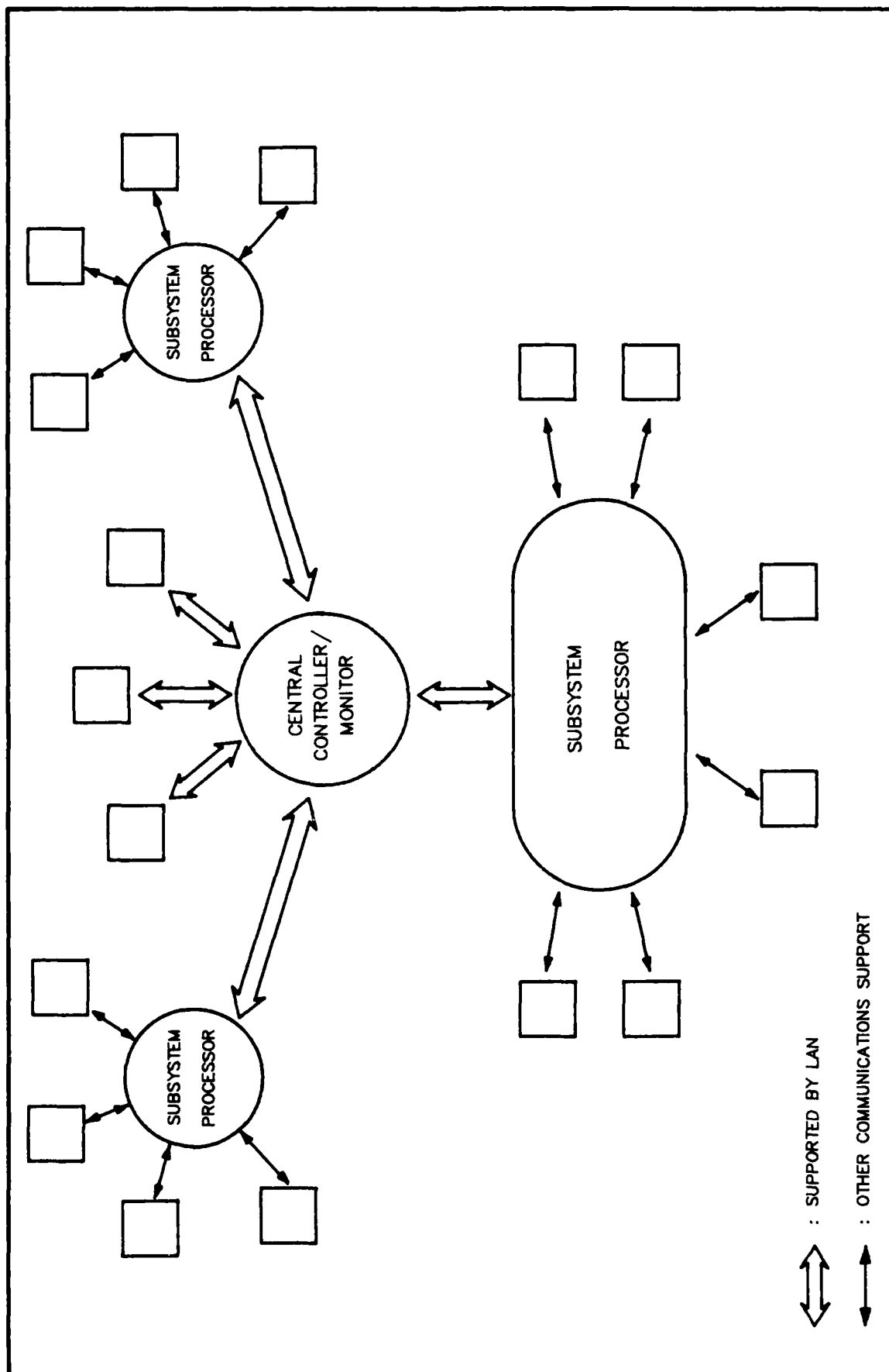
In light of the above-described state of affairs, two connectivity strategies relevant to the design of a control and status LAN have been identified:

- The control and status LAN supports control and status communications from all appropriate terminal equipment and processors, all such devices being connected to the LAN; or,
- The control and status LAN interconnects all control and status monitor processors and possibly some specific equipment components---other devices requiring control and status communications interact directly with their associated controlling/monitoring processor without use of the LAN.



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FIGURE 1-5: INTERCOMMUNICATION OF CONTROL AND STATUS DATA FROM ALL TERMINAL EQUIPMENT COMMUNICATION FLOWS AND FUNCTIONAL RESPONSIBILITIES



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FIGURE 1-6: INTERCOMMUNICATION BETWEEN CENTRAL PROCESSOR AND SUBSYSTEM PROCESSORS
ONLY COMMUNICATION FLOWS AND FUNCTIONAL RESPONSIBILITIES

The two connectivity strategies are represented in Figures 1-5 and 1-6, respectively; note, however, that these diagrams illustrate the LAN connectivity and are not meant to suggest the LAN topology.

These two design approaches reflect different control and status monitoring design philosophies as well as different LAN connectivities. The choice of control and status LAN design should not be made in isolation---the objectives of DSCS earth terminal control and status monitoring functions must be considered as well.

If all terminal equipment subject to remote control and status monitoring and the various controlling/monitoring processors intercommunicate via the control and status LAN, then, as in the full intercommunications LAN, an NIU is required for each attached device. As in the full intercommunications LAN, such NIU's must suit a variety of devices with a number of different interface requirements. This connectivity strategy, though, lends itself well to the goal of a fully integrated DSCS earth terminal, especially if a single central processor handles all control and monitoring functions.

If, on the other hand, the control and status LAN mostly supports peer-to-peer communications between subsystem processors and the interconnection between processors and devices is supported through other means, then less NIU's are required and many of their functions may be assumed by the processors themselves, reducing NIU complexity. Indeed, commercially available local area networks are typically most suited for this sort of processor-to-processor communications, suggesting that a cost-effective control and status LAN may be developed using off-the-shelf equipment. This connectivity strategy is evolutionary in the sense that it involves minimal change to the existing terminal equipment and will allow existing subsystem processors to either retain their present roles or defer responsibility to some new central processor. Again, however, the envisioned control and status monitoring system in an integrated DSCS earth terminal must be understood if an appropriate control and status LAN is to be designed.

Application of Digital Switching Technology

In addition to local area network technology, digital switching technology may be applied to provide the intercommunications required for DSCS subsystem integration. A digital switch used as an electronic patch panel between equipment groups provides configuration flexibility and automatic failover. The control of such a patch panel may be executed via a processor which provides automated terminal configuration management: the configuration of the electronic patch panel determines the configuration of the terminal equipment. Since the failure of the digital switch/electronic patch panel represents a single point failure for the terminal, it must support all signals within the terminal with high reliability. Use of the Integrated Multiplex, Patch, and Test (IMPAT)---currently under development by Martin Marietta specifically for military use---in fulfilling DSCS earth terminal interconnection requirements is considered here.

The IMPAT is a flexible multiplex and electronic patch device being developed for a variety of applications. In the transmit direction, IMPAT accepts user signals, routes them through its electronic patch, and may perform various multiplexing functions, all with a high degree of redundancy. While the current IMPAT design only permits inputs of less than 64 kbps, future enhancements are expected to increase this input capability to 1.5 Mbps or more. Use of the IMPAT has been considered in terms of both its current capability and assuming future enhancements.

In its current configuration, the IMPAT can provide electronic patching between the input user circuits and the first stage of multiplexers, replacing the first stage of multiplexers. Future IMPAT versions may have the capability to accept high rate inputs to the electronic patch panel, allowing multiplexer and other baseband equipment outputs to be fed back as inputs to the patch panel. With this capability, the IMPAT can be used to establish complete baseband equipment chains, eliminating the need for external multiplexers. This possible use of IMPAT assuming such future

APPLICATION OF DIGITAL SWITCHING TECHNOLOGY

- DIGITAL SWITCH (ELECTRONIC PATCH PANEL) MAY REPLACE EXISTING MANUAL PATCH PANELS, PROVIDING:
 - REMOTE CONTROL AND AUTOMATED TERMINAL CONFIGURATION MANAGEMENT
 - CONFIGURATION FLEXIBILITY
 - AUTOMATIC FAILOVER
- INTEGRATED MULTIPLEX, PATCH, AND TEST (IMPAT) CURRENTLY UNDER DEVELOPMENT BY MARTIN MARIETTA
 - PROVIDES ELECTRONIC PATCH AND REPLACES EXISTING MULTIPLEXERS
 - FUTURE IMPAT CAPABILITIES MAY ALLOW ITS USE TO ESTABLISH COMPLETE BASEBAND EQUIPMENT CHAINS

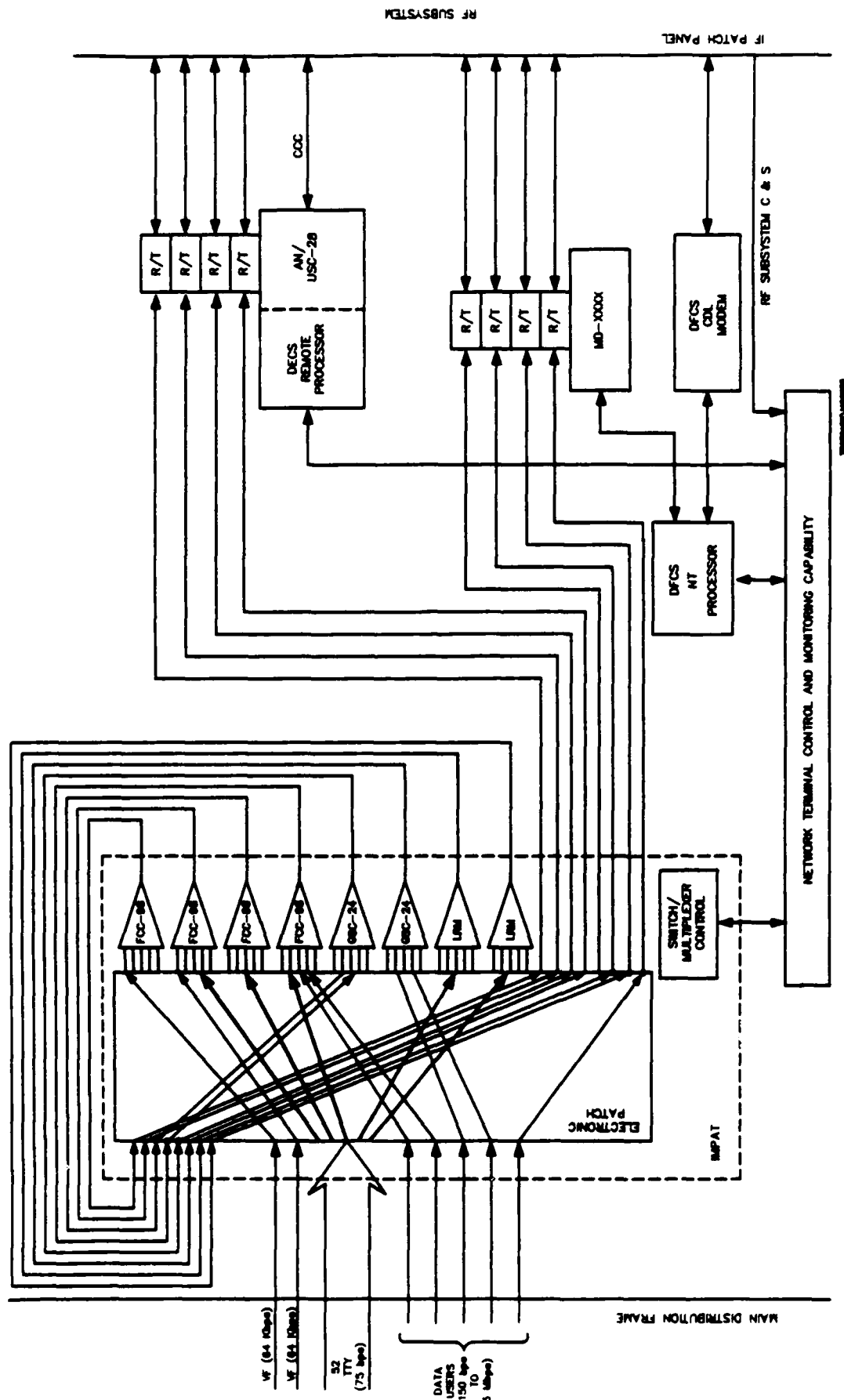


FIGURE 1-7: NETWORK TERMINAL CONFIGURATION WITH IMPAT

addition to such flexibility, the IMPAT provides a substantial space and power saving in comparison to the existing terminal multiplexers and manual patch panels.

Conclusions

This study, then, has examined the use of local area network and, to a lesser extent, digital switching technology in the support of DSCS earth terminal intercommunications. The information presented here provides a background into the capabilities of local area network technology and the needs of the envisioned application. Issues and considerations relevant to the communications requirements have been discussed, allowing an informed assessment of the available options.

SECTION 2

PROBLEM DEFINITION

2.1 INTRODUCTION

Integration of the DSCS earth terminal subsystems and equipment supported by local area network (LAN) technology involves two types of intercommunications. This section defines the earth terminal intercommunications problem, followed by a review of communications switching techniques and the types of switching supported by DSCS and typical local area networks.

The section concludes with a discussion of layered network architecture approaches to system intercommunications and the consequent role of local area networks in DSCS earth terminals.

2.2 DSCS SUBSYSTEM INTEGRATION REQUIREMENTS

The DSCS subsystems and equipment presently in existence or under development allow the modular construction of equipment configurations suitable for various terminal applications. Interconnection of these devices defines the needed equipment chains; i.e., the connection of the multiplexers, encryptors, codecs, modems, up/down-converters, and other components necessary to support the flow of signals through the DSCS earth terminal and thereby establish the DSCS user circuits. Other interconnections between devices allow (or will allow) computer control and status monitoring of these subsystems to reduce manpower requirements and provide increased system flexibility and efficiency. These two types of intercommunications between devices are thus necessary in the full integration of DSCS subsystems and equipment.

The first type of device intercommunication---that needed to support DSCS communication services---implies the establishment of dedicated channels through the terminal facility to preserve the transparency of the DSCS network with respect to system users. Equipment failure or routine maintenance may lead to the re-routing of signals through different components, but, once established, a DSCS satellite circuit generally is maintained for an extended period. Depending on the devices interconnected, however, the transmission rate between components varies. For example, multiplexing chains are often established as part of the terminal configuration, implying that the input and output connections may entail much different transmission rates. Any interconnection technique must be able to accommodate such variability.

The second type of device intercommunication, the exchange of status and/or control signals, however, would typically involve low data rate bursty communications. Such control and status transmissions are not as sensitive to the means of subsystem intercommunication as are the intercommunications involved in supporting DSCS services---transparency is not a paramount concern for these control and status signals. For example, delays incurred as a result of the intercommunications between devices may have little effect on device control and status monitoring but may dramatically degrade the perceived quality of user voice circuits.

DSCS SUBSYSTEM INTERCOMMUNICATION REQUIREMENTS

- INTERCOMMUNICATIONS BETWEEN DEVICES TO SUPPORT DSCS USER SERVICES
 - DEDICATED CHANNEL
 - LOW TO HIGH DATA RATES (≤ 10 MBPS)

- INTERCOMMUNICATIONS BETWEEN DEVICES FOR EQUIPMENT CONTROL AND STATUS MONITORING
 - LOW DATA RATES

2.3 SWITCHING TECHNIQUES

The Defense Satellite Communications System comprises a communications network, but so too may the interconnection of terminal equipment be considered to comprise a network. From the DSCS user's point of view, of course, there is only one network, implying that the interconnection of terminal devices must be made in a transparent fashion compatible with the workings of the DSCS network itself.

Switching techniques have traditionally been broadly classified as circuit-switching, message-switching, or packet-switching. The type of switching technique employed acts to define the character of a communications network.

Circuit Switching

In circuit-switching, an end-to-end path is established through the communications network, possibly through intermediate switches. Once established through a call set-up procedure, the communication path is dedicated to the users until their session is complete, after which the links are freed to be reallocated to other users. For short communications, however, the call set-up time may represent a major overhead; furthermore, if transmissions are not continuous, the exclusive allocation of the links comprising the end-to-end path results in an inefficient use of channel capacity.

Message Switching

In message switching, complete digital messages are transmitted through the communication network to the end user. In store-and-forward networks, a message is transmitted from node to node, stored at each node until locally accessed or relayed (forwarded) to the next node en route to the end destination. Routing of a message may be performed dynamically, each intermediate node of the network determining the next link en route to the

SWITCHING TECHNIQUES

- **CIRCUIT SWITCHING**
 - **END-TO-END DEDICATED CHANNEL FOR ANALOG AND/OR DIGITAL COMMUNICATIONS**
 - **EXCLUSIVE AND/OR CONTINUOUS SERVICE**
- **MESSAGE SWITCHING**
 - **TRANSMISSION OF COMPLETE DIGITAL MESSAGES**
 - **STORE-AND-FORWARD OR BROADCAST NETWORKS**
- **PACKET SWITCHING**
 - **DIVISION OF DIGITAL MESSAGES PROVIDES MORE EFFICIENT USE OF CHANNEL CAPACITY**
 - **STORE-AND-FORWARD OR BROADCAST NETWORKS**
- **DSCS PROVIDES CIRCUIT-SWITCHED USER SERVICES**
- **LOCAL AREA NETWORKS TYPICALLY PROVIDE PACKET-SWITCHED SERVICE**

final destination. The technique is not considered acceptable for most voice communications; for example, if speech is to be bidirectional and hence represented by more than one digital message, then the delays incurred by each message may vary as a result of different store-and-forward routings. Typically, then, message switching systems are used for applications where the end communications are in written form, as in telegrams or correspondence.

Packet Switching

Packet switching is similar to message switching except that a message is divided into fixed or variable length packets. Each packet contains the information needed to independently route the data to its destination; the full message is assembled from the received packets by the end user. In this way, more efficient use of channel capacity than achieved with message switching may be realized, especially when communications are of a bursty nature as is typical for computer-to-computer communications or character-by-character terminal communications.

Packetized voice communications are also possible, however, if such voice packets are handled as expeditiously as possible. For example, voice packets associated with a particular user should be transmitted through the network via a fixed end-to-end path in order to somewhat standardize the incurred packet delays and minimize the routing overhead. Additionally, other overhead involved in the transmission of voice packets may be minimized, perhaps by omitting error correction of such packets. This integration of voice and data over a packet-switched network necessarily involves increased intelligence at the network nodes, but is within the capabilities of current technology.

DSCS Switching Techniques

Like most telephone networks throughout the world, the DSCS network is a circuit-switched network, in this case providing dedicated satellite

circuits to the DSCS user community. User signals are typically time division and/or frequency division multiplexed to form the DSCS satellite channels. Both data and voice traffic are supported by the DSCS network, hence the interconnection of DSCS terminal equipment must interpose a minimal traffic delay. The packetization of data for communications within the terminal thus does not seem to be a reasonable alternative---if full terminal intercommunications are to be supported by local area network technology, alternatives consistent with the end-to-end operation of the DSCS network must be found.

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2.4 LAYERED NETWORK ARCHITECTURES

The interconnection of disparate devices such as anticipated in the integration of DCSS subsystems requires that a common basis for meaningful communications exist. In supporting DSCS communications, most of the terminal devices are already effectively transparent to the signals: a signal is routed, for example, from multiplexer to multiplexer to modem without any special handling or processing of the data along the way. In the case of the interchange of control and status signals between DSCS subsystems, however, it is not enough that units be connected by a common medium---the signals presented from one device to another must be significant to both. In other words, protocols must exist to enable the exchange of meaningful information.

The development of such protocols (or the application of existing ones) is further helped by some logical division of responsibility. Layered architectures have been developed to fulfill this need, examples being IBM's Systems Network Architecture (SNA), DEC's Digital Network Architecture, or the International Organization for Standardization's Open Systems Interconnection Reference Model. In these architectures, the layers are considered to be independent, with communications between connected entities governed by peer-to-peer protocols between corresponding layers, as suggested in Figure 2-1.

The OSI Reference Model

Although not universally adopted as a standard, the Open Systems Interconnection Reference Model perhaps best serves to illustrate the concepts involved in layered network architectures. Aware of the need for international standardization among manufacturers and vendors of information transfer and processing devices, the International Organization for Standardization (ISO) began in 1977 to define a framework for the development of standard communications protocols. The resulting International Standard Reference Model of Open Systems Interconnection

LAYERED NETWORK ARCHITECTURES

- INTERCONNECTION OF DISPARATE DEVICES REQUIRES STANDARDIZED MECHANISMS
 - INTERFACES
 - INTERACTIONS
- LAYERED ARCHITECTURE PROVIDES DIVISION OF FUNCTIONAL AND PROCEDURAL RESPONSIBILITIES
- CORRESPONDING LAYERS INTERACT ACCORDING TO ESTABLISHED PEER PROTOCOLS
- INTERNATIONAL STANDARDIZATION ORGANIZATION'S OPEN SYSTEMS INTERCONNECTION (OSI) REFERENCE MODEL PROVIDES FRAMEWORK FOR DEVELOPMENT
- IEEE PROJECT 802 COMMITTEE HAS PROPOSED LAN STANDARDS FOR LOWER LEVELS OF THE OSI REFERENCE MODEL

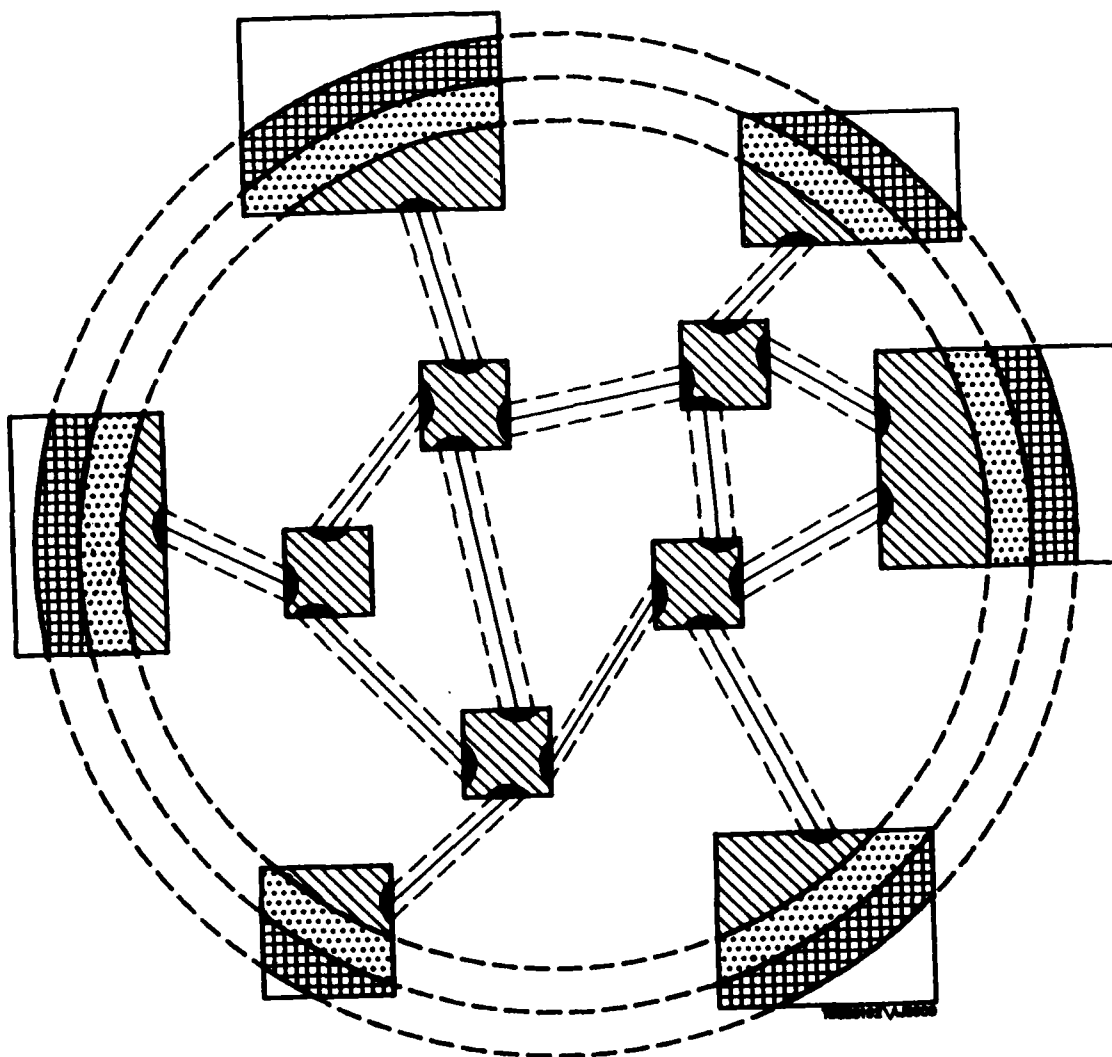


FIGURE 2-1: NETWORK LAYERING

establishes a layered architecture concept to model the interconnection of systems. The standard is not meant to precisely define the services and protocols needed in any particular application, but acts to provide an international basis for the development of such definitions. From the point of view of the Reference Model, a system is "a set of one or more computers, associated software, peripherals, terminals, human operators, physical processes, information transfer means, etc., that forms an autonomous whole capable of performing information processing and/or information transfer." A system is then "open" in the sense that conformance with international standards permits interconnection with all other systems also in compliance. The Open Systems Interconnection (OSI) architecture thus serves as a model of how conforming systems should appear externally to other open systems.

The OSI architecture models a network of interconnected systems as a hierarchy of layers of procedural and functional responsibility. As suggested by Figure 2-1, the layers span across individual systems, working outward from the lowest to the highest layer, building upon each other. Each layer augments the services provided by the lower layers so that, ultimately, the highest layer possesses the capability to administer the desired distributed process.

The intersection of a layer and a system may be seen as a subsystem; a layer is then simply all subsystems of the same rank in the interconnected network. Cooperation within the same layer is governed by that layer's protocols, thereby establishing the manner in which the services of lower layers are used to provide the capabilities required by higher layers. This representation of the layered architecture is often used to illustrate the OSI seven-layer Reference Model, as shown in Figure 2-2. The layered architecture allows individual protocols and service layers to be replaced or modified as needed without requiring changes in other parts of either the network or its individual components.

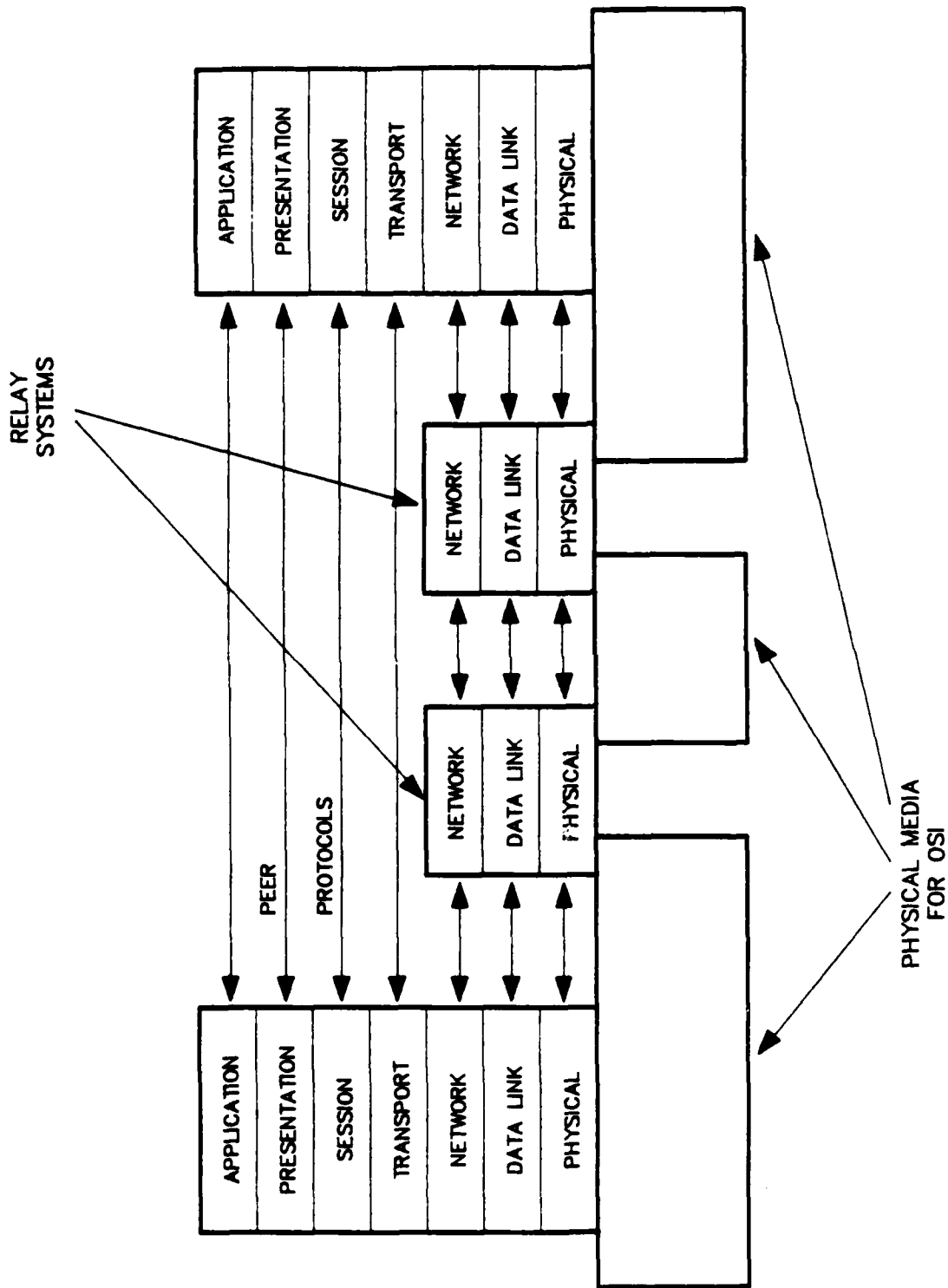


FIGURE 2-2: THE OSI REFERENCE MODEL ARCHITECTURE

LAYERS OF THE OSI REFERENCE MODEL

● APPLICATION LAYER

- DIRECTLY SERVES END USERS
- EXAMPLES: RESOURCE SHARING, FILE TRANSFERS, REMOTE FILE ACCESS, DATA BASE MANAGEMENT, NETWORK MANAGEMENT, ETC.

● PRESENTATION LAYER

- PROVIDES COMMON REPRESENTATION OF INFORMATION
- FURNISHES REQUIRED TRANSFORMATIONS BETWEEN SYNTAXES
- EXAMPLE: ISO STANDARD FOR "EXTENDED CONTROL CHARACTERS OF I/O IMAGING DEVICES"

● SESSION LAYER

- SUPPORTS PRESENTATION LAYER IN ESTABLISHING DIALOGUE
- ORGANIZES AND SYNCHRONIZES DATA EXCHANGE

● TRANSPORT LAYER

- PROVIDES END-TO-END CONTROL OF A COMMUNICATION SESSION ONCE THE PATH HAS BEEN ESTABLISHED
- EXAMPLE: IF-IP-SPONSORED INWG 96-1

LAYERS OF THE OSI REFERENCE MODEL (Cont'd)

● NETWORK LAYER

- PERFORMS ROUTING AND RELAY FUNCTIONS
- EXAMPLE: LEVEL 3 OF CCITT X.25 INTERFACE

● DATA LINK LAYER

- PROVIDES FUNCTIONAL AND PROCEDURAL MEANS TO ESTABLISH, MAINTAIN, AND RELEASE ERROR-FREE NODE-TO-NODE LINKS
 - FRAMES MESSAGES FOR TRANSMISSION
 - CHECKS INTEGRITY OF RECEIVED MESSAGES
 - MANAGES CHANNEL ACCESS
 - ENSURES PROPER SEQUENCE OF TRANSMITTED DATA
- EXAMPLES: ISO HIGH-LEVEL DATA LINK CONTROL (HDLC), ANSI ADVANCED DATA COMM. CONTROL PROCEDURES (ADCCP), IBM SYNCHRONOUS DATA-LINK CONTROL PROCEDURE (SDLC)

● PHYSICAL LAYER

- DEFINES THE ELECTRICAL AND MECHANICAL ASPECTS OF INTERFACING TO PHYSICAL TRANSMISSION MEDIA
- EXAMPLES: CCITT STANDARDS X.21, V.24, V.25, ETC.

Network Layering and DSCS Subsystem Intercommunication

The OSI Reference Model, then, establishes a seven-layer architecture: from highest to lowest, the Application, Presentation, Session, Transport, Network, Data Link, and Physical Layers. This seven-layer architecture provides a framework within which to consider the development of any interconnection of devices. The lower levels of the ISO Reference Model are most pertinent to the design of local area networks and the problem of DSCS subsystem intercommunications.

DSCS terminal equipment is effectively transparent to end-to-end users of the communications facility. Any local area network used to integrate DSCS equipment must similarly be transparent. In terms of the OSI Reference Model, the entire Defense Satellite Communications System effectively comprises a network of relay systems connecting the end users.

If a local area network is used for the communication of control and status signals between terminal equipment, then, while the local network provides the means by which such signals are relayed, higher level protocols must exist to facilitate and govern the interaction of the communicating devices. It is not within the scope of this effort to consider the nature of such higher-level functions; a local area network merely provides the means to transfer data among attached devices with no guarantees as to the correct interpretation of that data.

SECTION 3

DSCS TERMINAL DEFINITION

3.1 INTRODUCTION

The Defense Satellite Communication System is a circuit switched network providing communications via a high capacity Phase Shift Keyed (PSK) Frequency Division Multiple Access (FDMA) network when unstressed and a limited capacity Spread Spectrum Multiple Access (SSMA) network under stressed conditions. The resulting network is composed of satellite transponders, earth terminals, and control elements. Each earth terminal supports a portion of the FDMA and SSMA communication networks and a portion of the control of each network.

The focus of this study is the intercommunication of equipment and subsystems within the earth terminals in the DSCS. To accomplish this goal, equipment and subsystem configurations which reflect current and future trends in DSCS earth terminal design must be identified and intercommunication requirements for these configurations evaluated. This section, then, identifies terminal equipment and subsystem configuration in current and future earth terminals, and identifies the communication, control, and monitoring integration requirements of subsystems and associated equipment. Information about relevant DSCS subsystems and basic terminal configurations is first provided as background, then specific representative terminal configurations which can be used to evaluate intercommunication solutions are developed and presented.

This section begins with definitions and operational aspects of the DSCS subsystems, followed by a description of the four possible logistic terminal configurations. Three baseline terminal equipment configurations (light, medium, heavy) and their interactions with DSCS subsystems are then outlined. Finally, the integration of communication, control and status signals among the subsystems is discussed.

3.2 DSCS SUBSYSTEMS

Several subsystems which are part of the DSCS have a direct impact on the integration of the DSCS earth terminals. The definition and operational considerations of these subsystems is presented here as background information.

Digital Communication Subsystem (DCSS)

The DCSS portion of the DSCS comprises the baseband equipment located in the earth terminals. Its function in the baseband to IF direction is to accept various baseband user signals (data, voice frequency (VF)), digitize (if necessary), and multiplex them into higher rate digital signals suitable for transmission over a digital satellite link, perform the necessary encryption and channel coding, and modulate the resulting high rate baseband data to the IF carrier. A DCSS is located at each earth terminal and is compatible with the DCSS located at any other terminal in the network. The DCSS is configured so that a user circuit from one earth terminal to another passes through the same equipment chain at each terminal; in this way the DCSS is used to control circuit switching in the network. Presently most of the DCSS equipment does not permit remote monitoring or control; however, in future implementations the DCSS equipment may be monitored by a Fault Status Monitor which will interface with the network control systems, DFCS and DECS. The location of the DCSS in an earth terminal depends on the terminal configuration, as discussed in Section 3.3: it may be housed in a different building or shelter than the earth terminal and/or it may be physically split into two facilities with multiplexers in one facility and modems in another.

DSCS Operational Control System (DOCS)

DOCS has the responsibility of control and monitoring of the overall DSCS network. It provides centralized control of the network via the DSCS FDMA Control Subsystem (DFCS), the DSCS Electronic Counter-Counter Measure (ECCM) Control Subsystem (DECS), the DSCS Operational Support System (DOSS)

DSCS SUBSYSTEMS

- DIGITAL COMMUNICATIONS SUBSYSTEMS (DCSS)
- DSCS OPERATIONAL CONTROL SYSTEM (DOCS)
- DSCS FDMA CONTROL SYSTEM (DFCS)
- DSCS ECCM CONTROL SYSTEM (DECS)
- DSCS OPERATIONAL SUPPORT SYSTEM (DOSS)
- RF SUBSYSTEMS

and other subsystems. These subsystems consist of processing equipment to execute control and monitor status of equipment in each terminal, secure communication channels to link central and remote processors, and central processors to evaluate status reports and generate control commands.

DSCS FDMA Control Subsystem (DFCS)

The DFCS is that portion of the DOCS which is responsible for the centralized control of the FDMA DSCS circuits. The DFCS is composed of a central processing unit located at the Network Control Terminal (NCT) and remote processing units located at the Network Terminals (NT's). The DFCS central processor at the NCT broadcasts control commands to the remote units and polls the remote units to acquire monitoring information, communicating via a Control Data Link (CDL) using CDL modems. A diagram of the DFCS and the interaction of its components is provided in Figure 3-1.

In each NT, then, the remote units interact with their associated equipment and communicate with the DFCS central processor at the NCT. The remote units execute commands from the central unit to control transmit power and monitor receive and transmit carrier power, Pseudo Bit Error Rate (PBER), IF C/kT, and the outputs of the proposed NT Fault Status Monitor. There is also a capability to interface with the Adaptive Link Power Control (ALPC) system, an RF subsystem controller.

The DFCS central processing unit in the NCT monitors the NCT status and polls the NT's over the CDL via frequency division multiple access channels to obtain terminal status. Up to 16 NT's can be polled over one CDL. Commands are similarly broadcast to the NT's over the CDL. The network status monitoring information is displayed to the network operator and is also sent to the DSCS Operational Support System (DOSS). The DOSS evaluates the status information and generates commands to be sent to the remote components, although commands may also be generated by the network operator. In addition to originating commands, DOSS is used for database transfer to the remote unit and for initialization of the FDMA system.

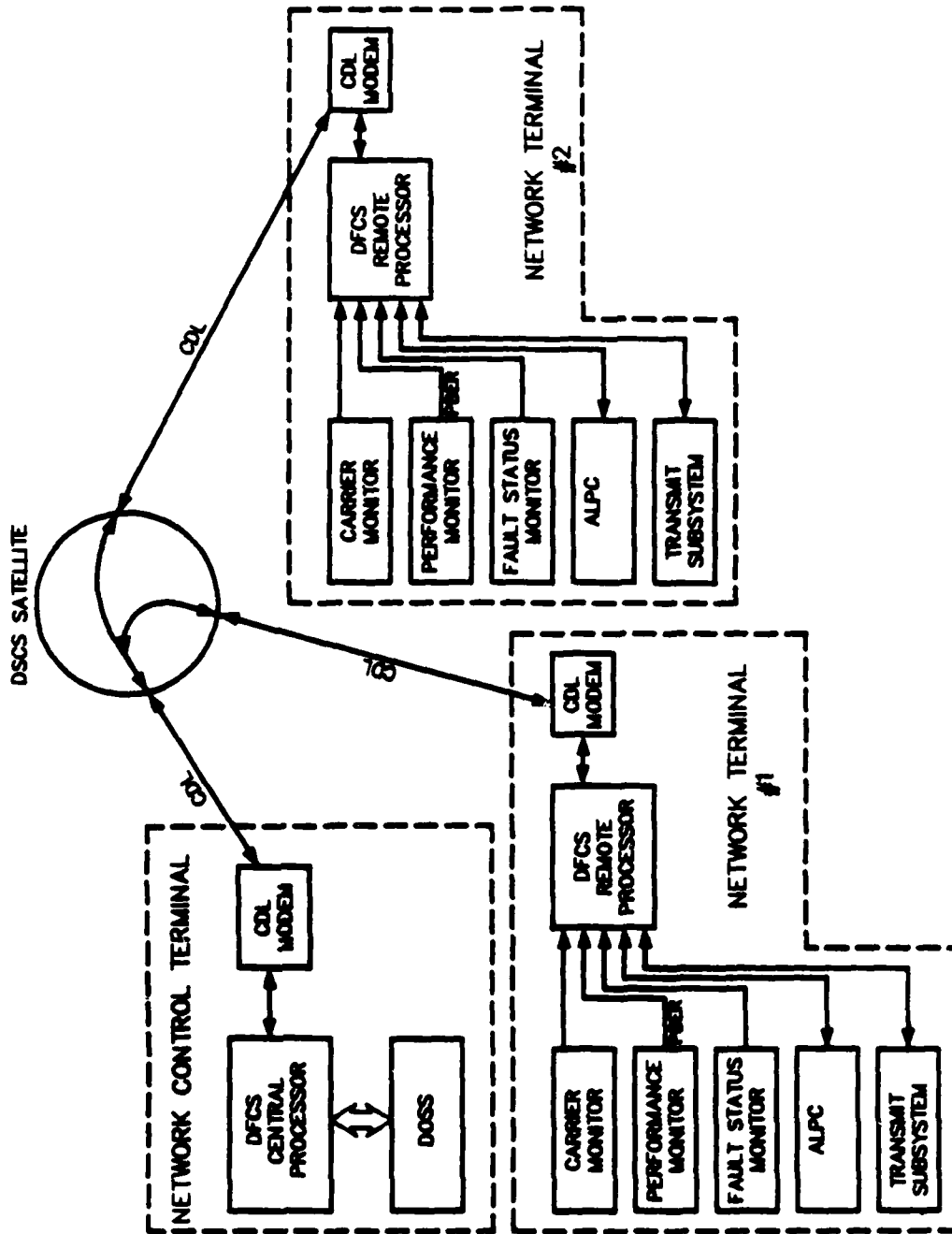


FIGURE 3-1: DSCS FDMA CONTROL SUBSYSTEM (DFCS)

DSCS ECCM Control Subsystem (DECS)

The DECS performs centralized control and status monitoring functions for the electronic counter-counter measure (ECCM) network within the DSCS. The DSCS ECCM network supports continuous full duplex user links at rates from 75 bps to 1.5M bps. Since satellite resources are nearly fully utilized and subject to stringent availability requirements, it is important to monitor signal quality, satellite loading, and earth terminal equipment status and be able to control operation parameters to maintain optimum resource usage. These considerations have lead to the development of the DSCS ECCM control subsystem. The major components of the DECS are the central component located at the Network Control Terminal (NCT), the remote component located at the Network Terminals (NT's), and the Critical Control Circuits which provide communication between the remote and central components. The interaction of these components is illustrated in Figure 3-2.

As an overview, the DECS is a centralized network monitoring and control system using the capabilities of the AN/USC-28 modems and the Critical Control Circuit (CCC) available in the DSCS. The DECS accomplishes network optimization by performing the following control and monitoring functions:

- Power monitoring: the signal strengths of all USC-28 transmissions are measured by monitoring all transmissions from the NT's received at the central DECS component (located at the Network Control Terminal).
- Polling: terminal and USC-28 status is transmitted from the NT's via return CCC to the NCT from all terminals where it can be monitored by the DECS.
- Network Control: remote and automatic link scheduling and equipment configuration via the CCC from NCT to the NT (central to remote DECS component).

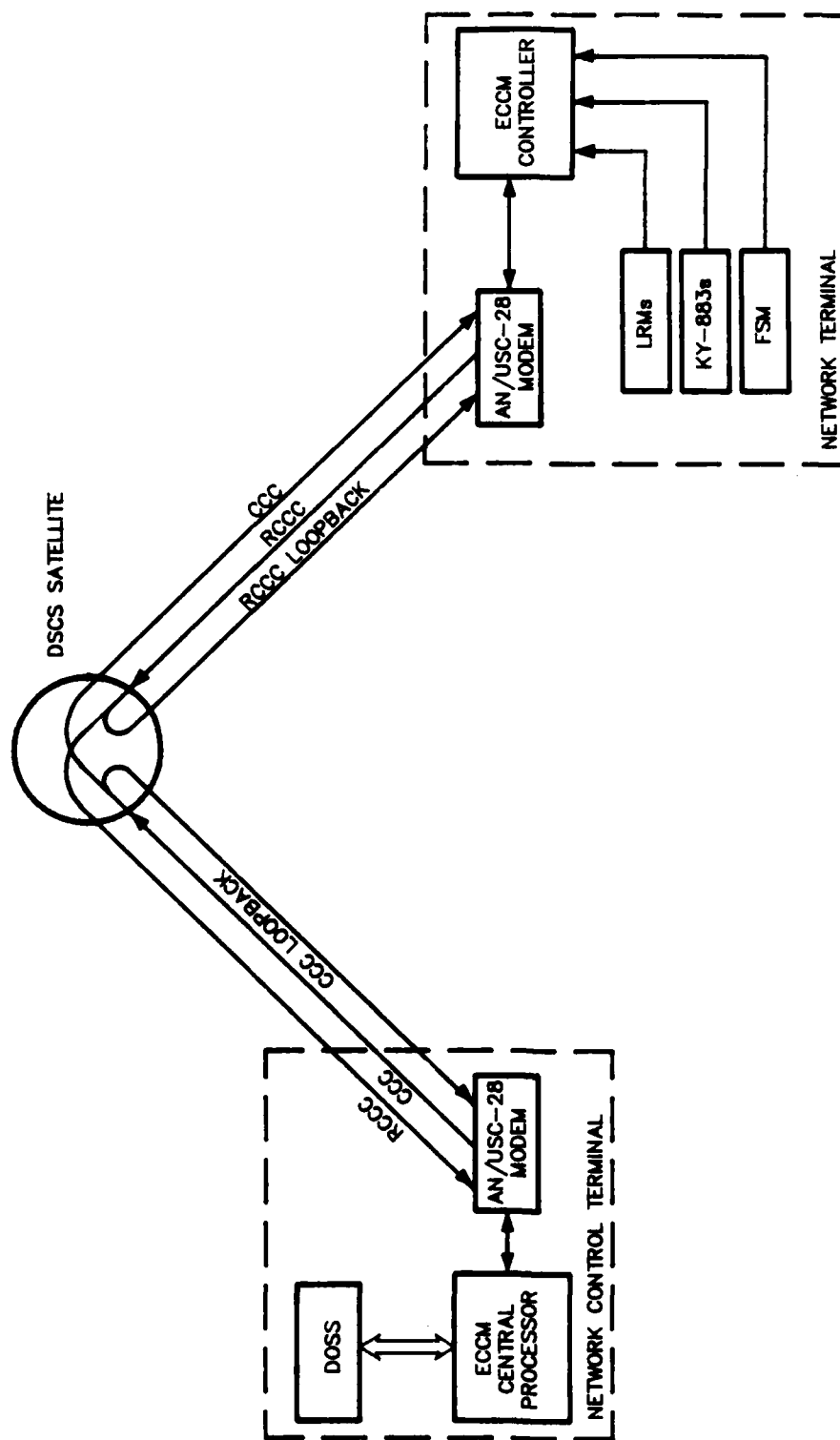


FIGURE 3-2: DSCS ECCM CONTROL SUBSYSTEM (DECS)

- Jamming analysis: loop back of transmitted signals to the originating USC-28 allows for measurement of the satellite power level. This calibration permits the detection of pulsed jammers, etc.
- Interaction with DSCS Operational Support System (DOSS): link between DECS and DOSS or man machine interface to send poll responses and terminal status from DECS, and to receive commands and configuration control from the DOSS or man machine interface.

Each AN/USC-28 modem in the ECCM network consists of receive/transmit (R/T) units dedicated to supporting the DECS Critical Control Circuits, R/T units allocated to support ECCM user communications, and a modem control unit. A DECS processor is provided for each AN/USC-28 modem which provides a control and monitoring interface to the modem control unit as well as a communication interface to the CCC R/T units via KG-84 encryption units. The DECS processor also provides control and monitoring capabilities for the KY-883 codecs and the Low Rate Multiplexers (LRMs).

At the Network Control Terminals, the DECS processor interfaces with the AN/USC-28 modem, ECCM baseband equipment, and the DSCS Operational Support System to communicate control and monitoring signals. At Network Terminals the DECS processor supports interfaces with AN/USC-28 modems and associated ECCM baseband equipment, including the Low Rate Multiplexers, KY-883 codecs associated with the Critical Control Circuits, and the future Fault Status Monitor.

Presently the DECS is implemented in the following manner. ECCM network control signals are generated at the Network Control Terminal by an operator interacting independently with the DOSS. Control signals are then broadcast via the USC-28 to one receiver unit in each USC-28 in the network. While control signals commanding the USC-28 are accepted automatically, control commands for other equipment at the network terminals are sent to a teletype and actually implemented by the local operator. Similarly, USC-28 status and the status of associated devices

are monitored in each NT by the DECS processor; other equipment status information is reported hourly by the network terminal operator to the local DECS processor. Status information is formatted into polling messages at each network terminal and continuously broadcast on the return critical control circuit; the USC-28 at the NCT then scans the return critical control circuit for each NT status signal and sends the information to the central DECS control computer for use and display.

The above operational description of the ECCM control system and the "Type A Specification For DSCS ECCM Control Subsystem" reveal aspects of the handling of control and status signals by DECS at the DSCS earth terminals. Present equipment generally indicate status via front panel display and/or audio-visual alarms to the operator, necessitating operator intervention. New equipment and equipment being developed (the USC-28, IMPAT, FSM, LRM, etc.), on the other hand, provide remote status and alarm signals designed for processor interface. Similarly, control of the new equipment may be accomplished via remote interface to a command processor. Presumably these features will be available in all new equipment. In addition, an upgrade to DOSS, currently under development, will provide for direct communication between the DECS central processor and DOSS at the DSCSOC's, the DSCS Operations Centers.

DSCS Operational Support System (DOSS)

The DSCS Operational Support System is the central element of the DOCS, providing the equipment and software for the network managers to allocate resources in the DSCS networks and centralize network control and monitoring. The primary functions of DOSS are to:

- Summarize network status information and provide reports to the network managers;
- Perform network planning through the use of resource allocation software;

- Produce network configuration data based on the network plan developed; and,
- Disseminate network configuration data to the appropriate DSCS subsystems.

As a result of the current DOSS upgrade, DOSS will interface directly with DECS for ECCM network control, DFCS for FDMA network control, the DSCS Automatic Spectrum Analyzer (DASA) to monitor satellite transmissions, the Smart Multi-Circuit Terminal (SMCT) for access to Terrestrial Critical Control Circuits, the Satellite Configuration Control Element (SCCE) for satellite payload command, and the DSCS Operations Center Patch and Test Facility (PTF) for inter-site communications.

RF Subsystems

The RF subsystems in DSCS terminals provide up- and down- conversion between RF and IF and establish transmit and receive power levels. Current trends in earth terminal design provide control, status monitoring, and remote capabilities. Such a design philosophy is incorporated in the Modularized Integrated Satellite Terminal (MIST), the Ford Aerospace SCT-8, and the State of the Art Medium Terminal (SAMT). To complete the earth terminal definition, a discussion of the SAMT as a typical DSCS RF subsystem is presented, including the SAMT interfaces to other equipment in the terminal.

The SAMT is a high-capacity, medium-size RF satellite terminal currently under development by Ford Aerospace and Communications Corporation. The communication flows in the SAMT are illustrated in Figure 3-3: modulated IF signals from the baseband equipment enter the IF patch, are upconverted to several frequency bands, combined, amplified, and transmitted over the satellite channel; a similar down- conversion process is applied to the received signal. The SAMT is functionally broken into several subsystems which are under the control of a central terminal processor.

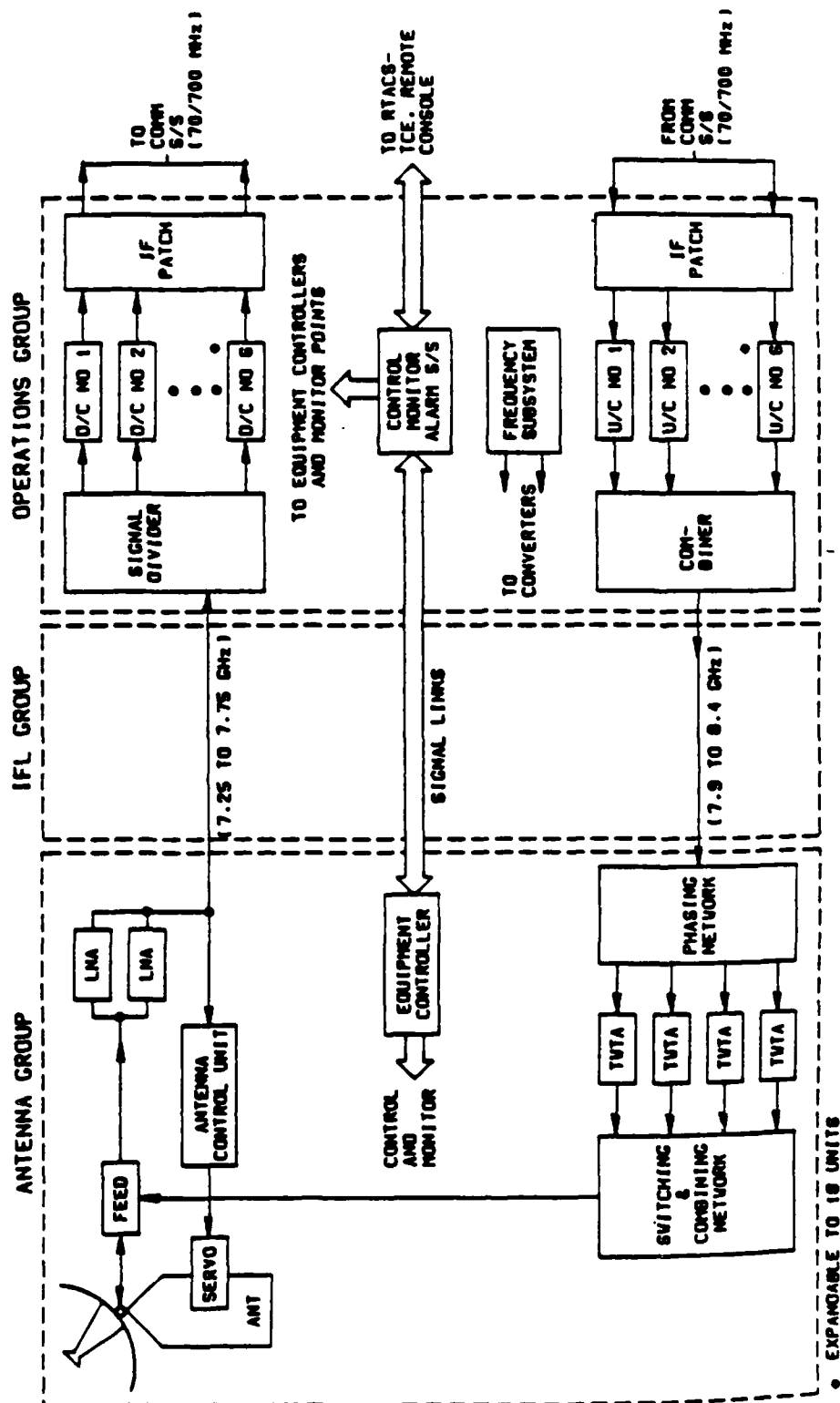


FIGURE 3-3: SAMT SIMPLIFIED BLOCK DIAGRAM

(FROM SAMT DESIGN REVIEW, FORD AEROSPACE)

The SAMT is designed for manned or unmanned operation centralized by a control, monitor, and alarm (CMA) subsystem. The CMA subsystem provides performance monitoring, equipment calibration, and fault isolation allowing unattended operation and automatic equipment switchover in the event of a failure. In addition to controlling SAMT equipment, the SAMT terminal processor provides control and status monitoring interfaces for baseband equipment operating in the terminal. The CMA subsystem employs a distributed architecture with a central terminal processor (VAX-11/730) and local controllers associated with each of the terminal subsystems. Control and status interfaces of the SAMT are depicted in Figure 3-4. The local controllers interpret the terminal processor commands and configure the equipment accordingly. The SAMT CMA distributed architecture allows control from the terminal processor as well as from the local controllers and the equipment front panels. The local controllers are implemented as cards in the equipment chassis with RS-232-C interfaces to the terminal processor. Although the local controllers include circuitry unique to the specific equipment they control, they are designed to provide a degree of hardware and software commonality.

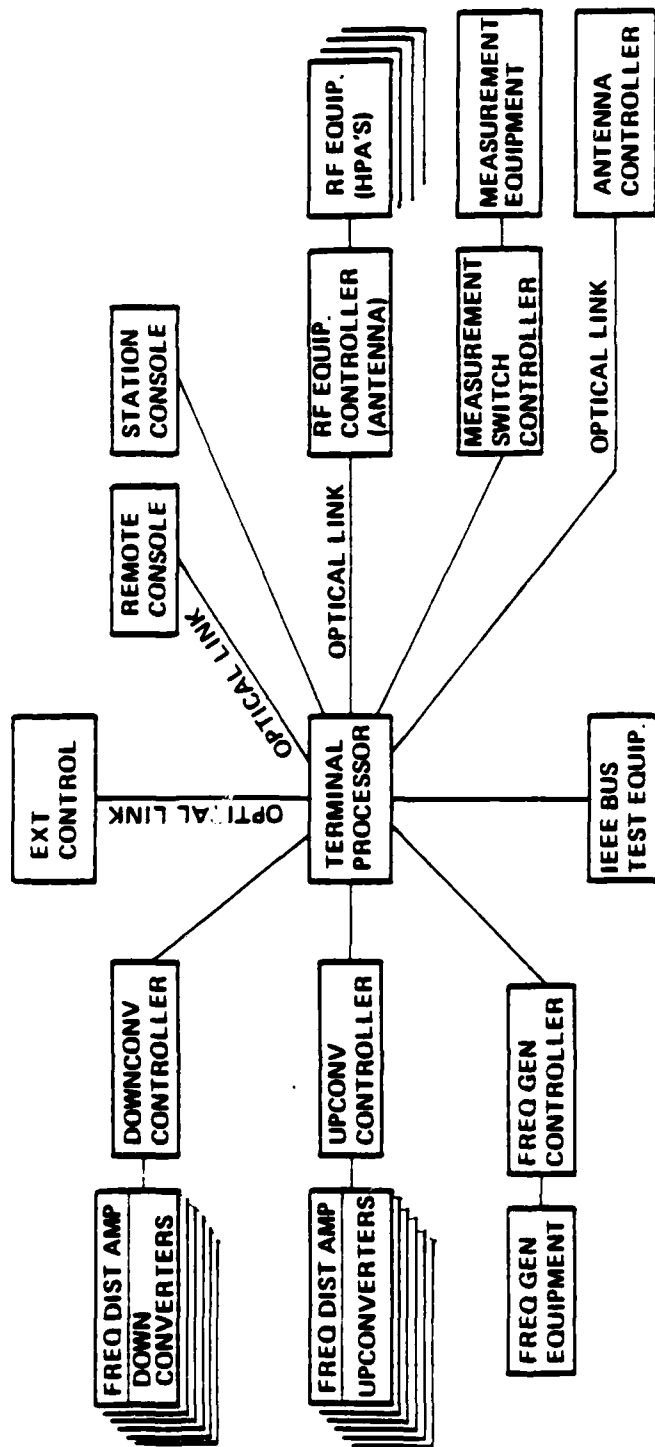


FIGURE 3-4: CONTROL, MONITOR AND ALARM (CM&A)
(FROM SAMT DESIGN REVIEW, FORD AEROSPACE)

3.3 TERMINAL CONFIGURATIONS

Each earth terminal in the DSCS network performs communication processing to prepare user signals for transmission over the satellite channel and to extract user signals from the received satellite signal. The way in which the communication processing is performed will determine to an extent the way in which the communications equipment is integrated in the earth terminals. Processing responsibility in DSCS earth terminals is divided among the Technical Control Facility (TCF), the Digital Communications Subsystem (DCSS), and the Link Terminal. In some cases the Link Terminal and TCF may be physically separated; for these cases an Interconnect Facility (ICF) is provided to allow transparent communication between the Link Terminal and the TCF. The Technical Control Facility provides an interface to DSCS users, performing any necessary signal conditioning required to produce a DSCS-compatible signal. The DCSS accepts these signals and performs multiplexing, coding, encryption, and modulation to produce the IF signal suitable for transmission through a DSCS satellite channel. The Link Terminal provides the facilities for transmission and reception of the RF satellite channels. Note that DSCS nomenclature typically uses the term "Earth Terminal" or "ET" to refer to the DCSS and Link Terminal capabilities in order to distinguish those services from the user interface provided by the TCF.

There are four different cases of earth station configuration, as shown in Figure 3-5. The configuration of a given earth terminal will depend on the geographical and logistical characteristics of the site. The differences in each case are the location of DCSS processing (in the TCF or ET facilities or both) and the link employed by the Interconnect Facility. In Case I, the TCF and ET are closely situated in two separate buildings. The ICF consists of baseband coaxial cables and DCSS processing is located in the earth terminal. In Case II, the TCF and ET are separated by a distance requiring microwave or fiber optic communication in the ICF. DCSS processing responsibility is split, with modulation in the ET, and multiplexing and coding located at the TCF. In Case III, the TCF and ET are located in

the same building/shelter; the interconnection is provided by baseband cable and all DCSS processing is performed in the ET. The configuration of Case IV pertains to closely located TCF and ET in two separate buildings interconnected by baseband cable or fiber optics. DCSS processing responsibility is split between the TCF and the ET. In cases where the DCSS signal processing is split between two locations some type of communications resource (ICF or other) must be provided to support control and status monitoring for full terminal integration.

EARTH TERMINAL CONFIGURATIONS

- CASE I
 - TECHNICAL CONTROL FACILITY (TCF) ACTS ONLY AS AN INTERFACE TO USERS
 - INTER-CONNECT FACILITY (ICF) CONNECTS TCF WITH THE EARTH TERMINAL (ET) CONTAINING ALL DCSS FUNCTIONS (E.G., MULTIPLEXING, MODULATION) OVER SHORT DISTANCES VIA BASEBAND CABLE
- CASE II
 - DCSS FUNCTIONS ARE SPLIT BETWEEN TCF AND ET
 - DIVISION OF DCSS IS SITE-DEPENDENT
 - ICF CONNECTS THE TWO PARTS OF DCSS VIA LINE OF SITE COMMUNICATIONS (UP TO SEVERAL MILES)
- CASE III
 - TCF AND ET ARE CO-LOCATED, WITH DCSS AS PART OF ET
- CASE IV
 - DCSS FUNCTIONS ARE SPLIT AS IN CASE II
 - ICF USES CABLE OVER SHORT DISTANCES (BETWEEN BUILDINGS)

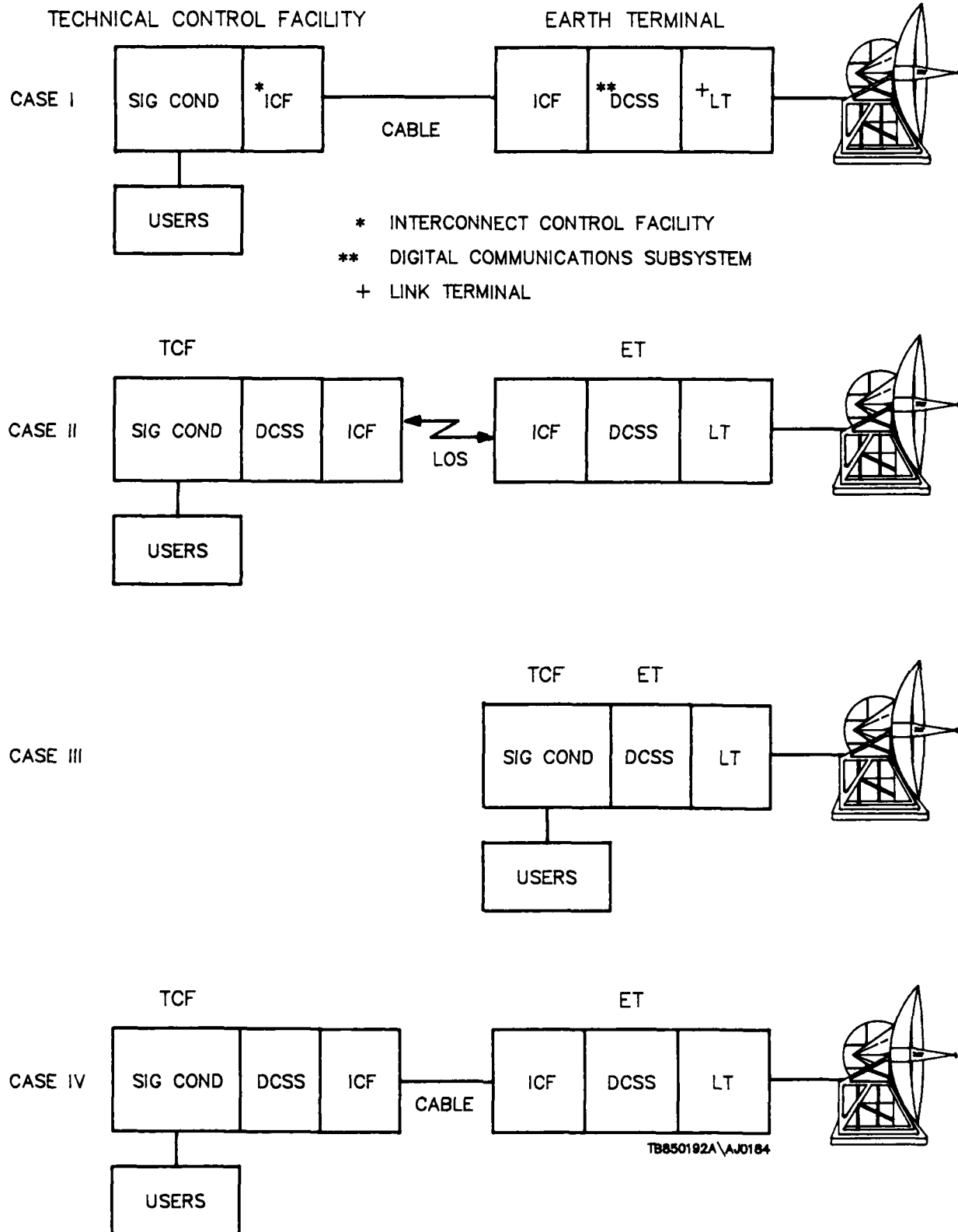


FIGURE 3-5: EARTH STATION CONFIGURATIONS

3.4 EQUIPMENT CONFIGURATIONS

The previous sections discuss the responsibility of various subsystems in DSCS. In order to investigate the intercommunication and integration needs of DSCS terminal equipment and subsystems, equipment configurations and the associated connectivities and interfaces among subsystems and equipment must be identified. The equipment configurations of the Digital Communications Subsystem in the DSCS terminals are emphasized here. Since terminal configurations vary from terminal to terminal based on geography, loading, priority, etc., the generic equipment configuration of Figure 3-6 will serve as a basis. In this configuration three basic equipment groups are identified--- multiplexer, modem, and RF---with the multiplexer group and modem group detailed further in Figures 3-7 and 3-8, respectively.

In the transmit direction, user signals typically arrive from the TCF via a main distribution frame from which they are routed to multiplexing, encryption, and coding equipment. The output of equipment in this group is fed into the modem inputs; the modulated IF output is then sent to the RF equipment for upconversion and transmission. In addition to these three groups, Figure 3-6 shows a control and status monitoring capability providing control and monitoring access to equipment in the terminal.

The multiplexer group of equipment is typified by the configuration of Figure 3-7. Low rate user signals (≤ 64 kbps) are time division multiplexed into several higher rate signals for modulation to IF. The AN/FCC-98 low rate multiplexer accepts 24 voice or data inputs each up to 64 kbps while its maximum output rate is 1544 kbps; the AN/GSC- 24 multiplexer accepts inputs of rates from 50 bps to 3 Mbps and produces an output limited to a rate of 10 Mbps. These particular multiplexers are not equipped to generate and/or accept status and control signals; however, other DSCS earth terminal multiplexers such as the Low Rate Multiplexer (LRM) and the future Integrated Multiplex, Patch, and Test (IMPAT) do provide control and monitoring access and, if full terminal integration is to be realized, require connectivity to a control and monitoring capability.

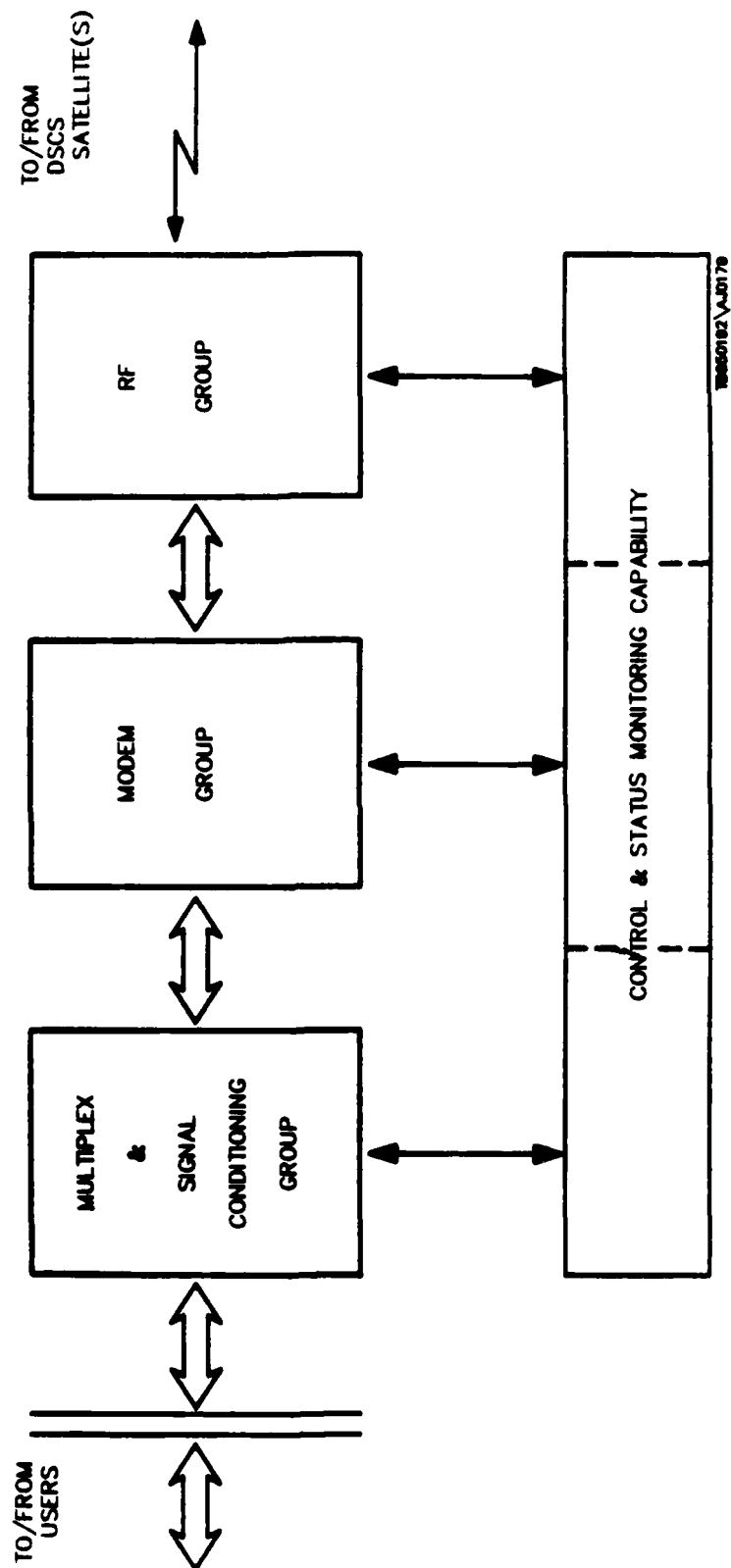


FIGURE 3-6: DSCS TERMINAL EQUIPMENT

A similar typical configuration is shown in Figure 3-8 for the modem group of equipment. Two modem types corresponding to the Electronic Counter-Counter Measure network and the FDMA network are employed in the terminal. The AN/USC-28 spread spectrum modem is used for ECCM user communications as well as ECCM control and monitoring communications and interfaces directly with the processing unit of the DSCS ECCM Control Subsystem; the AN/USC-28 modem contains up to 15 receive/transmit units which modulate a 70/700 MHz IF carrier with rates up to 2.5 Mbps. The MD-XXXX modem is a non-ECCM BPSK/QPSK modem currently in development; each receive/transmit unit of the MD-XXXX modulates the IF carrier with signals of rates from 16 kbps to 20 Mbps (QPSK, no coding). A master controller module within the MD-XXXX is responsible for up to 16 receive/transmit modules and provides automatic external control and monitoring capabilities. The AN/USC-28 and MD-XXXX are also compatible with the coding/-decoding equipment (KY-801, KY-883) at all modem rates. The KY-883 codec provides a control and status monitoring interface to the DECS processor associated with the ECCM modem with which it operates.

In the design of earth terminals it is desirable to allow for a measure of fault tolerance achievable through the use of redundant equipment and switching capabilities. At present, redundant equipment is manually switched on-line via patch panel when a terminal element fails. In future configurations it may be desirable to employ electronic patching which can be automatically controlled when an equipment failure is detected.

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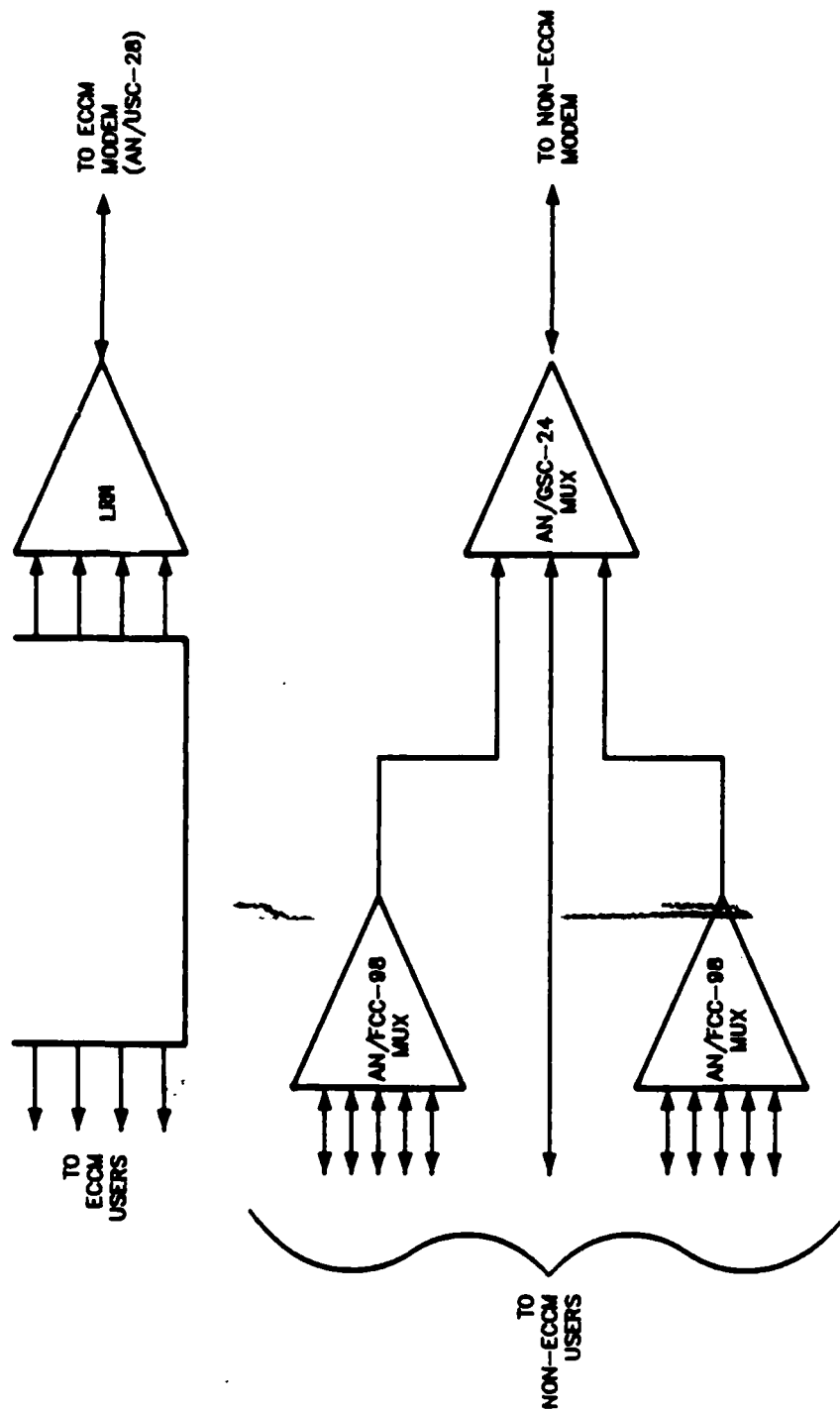


FIGURE 3-7: TYPICAL MULTIPLEXER CONFIGURATION

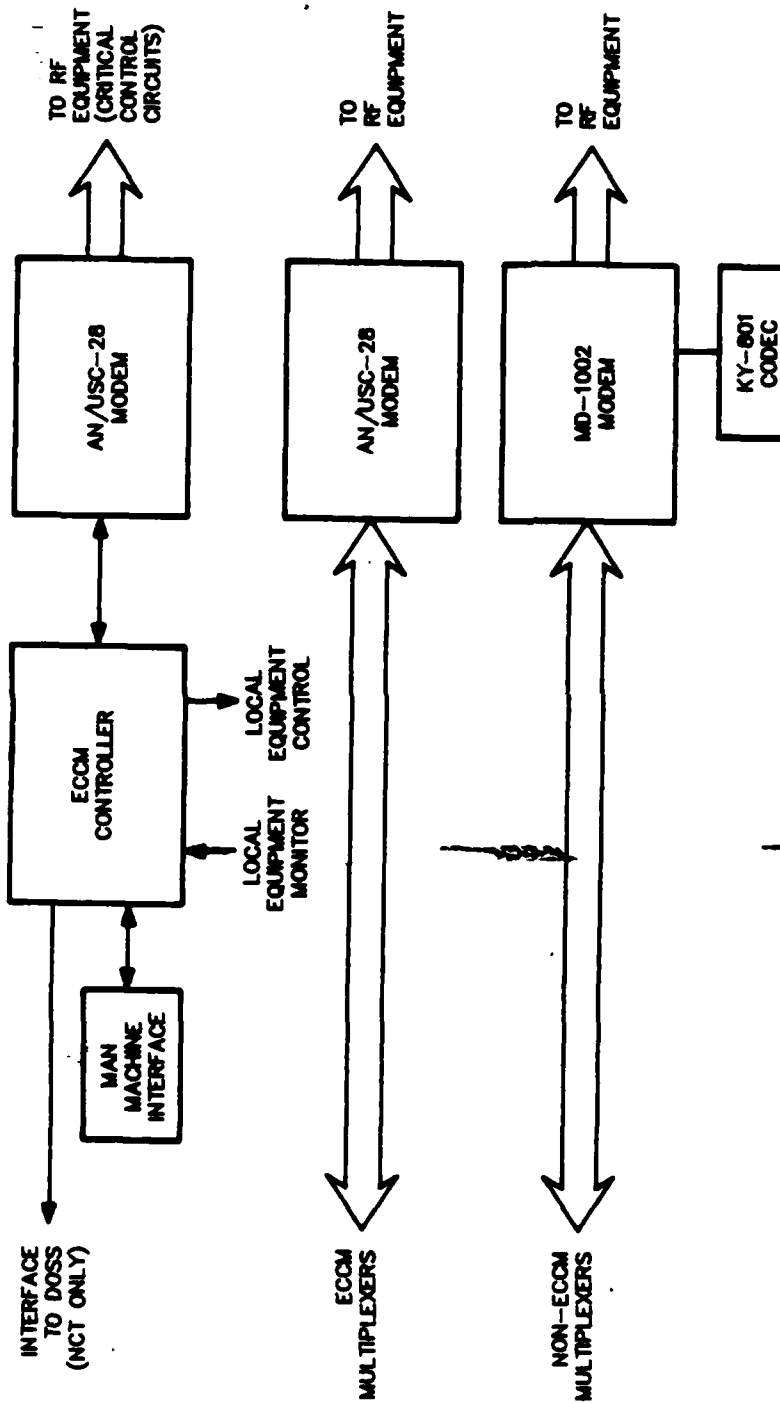


FIGURE 3-8: TYPICAL MODEM CONFIGURATION

3.5 BASELINE TERMINAL CONFIGURATIONS

Given that the equipment configuration varies from terminal to terminal, three baseline terminal configurations to cover three ranges of loading (in terms of aggregate user data rate) are defined in order to evaluate DSCS subsystem intercommunication solutions. Each configuration is based on the information presented in the previous sections regarding communications connectivities, interfaces to control subsystems (DECS and DFCS), and the DSCS user community. These terminal configurations are then used as a testbed for possible intercommunication solutions.

Requirements for future DoD earth terminals assume an integrated design philosophy and call for:

- Standardization of equipment and associated interfaces to reduce life cycle costs;
- Centralized configuration control and performance and status monitoring;
- Fault detection and failover capabilities; and,
- Remote control capabilities.

Such features are inherent in the proposed Modularized Integrated Satellite Terminal (MIST) concept; therefore, the MIST is used in this study as the baseline configuration for a light terminal (aggregate user data rate less than 10 Mbps). Figure 3-9 shows the communications, control and monitoring connectivities for the light baseline terminal. User signal and equipment data are presented for all three baseline configurations in Tables 3-1 and 3-2, respectively. Since the actual configuration of each terminal varies, Figure 3-9 suffices to illustrate the connectivities present in medium and heavy terminals as well as in light terminals, although the number of devices will, of course, be different.

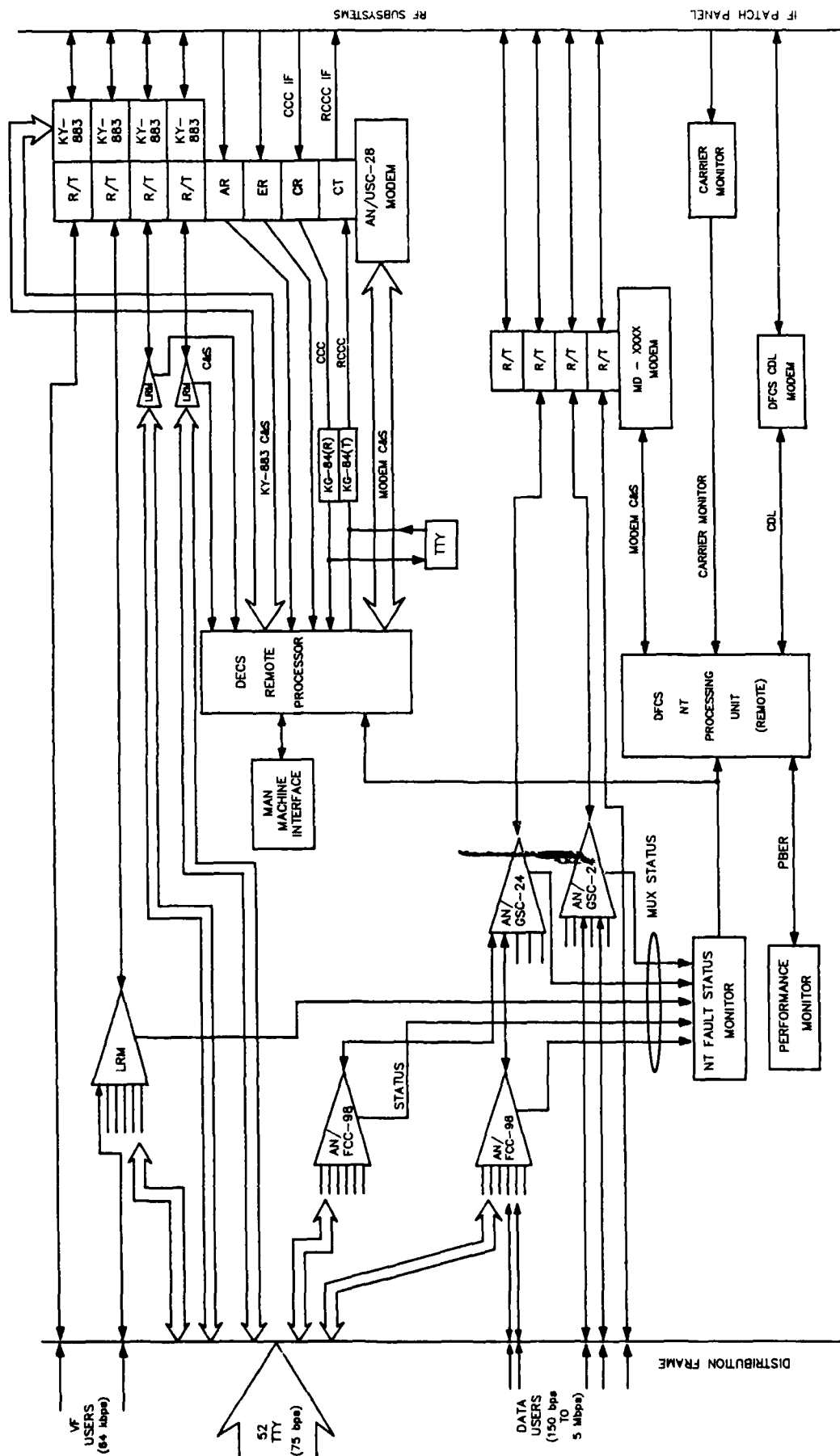


FIGURE 3-9: BASELINE NETWORK TERMINAL (LIGHT)

TABLE 3-1
BASELINE USER CHANNELS

USER SIGNALS	LIGHT (MIST BASELINE)	MEDIUM	HEAVY
VOICE (64 KBPS)	2	85	111
SECURE VOICE	-	2 (2.4 K)	5 (2.4 K), 1 (16 K)
TTY (75 BPS)	52	-	-
DATA (BPS)			
> 6 M	-	-	3 (6.3 M)
3 - 6 M	1 (5M)	1 (3.2 M)	1 (3.072 M)
1 - 3 M	1 (1M)	1 (1.544 M), 1 (1.6 M)	2 (1.544 M)
.3 - 1 M	-	-	2 (385 K)
200 - 300 K	-	-	2 (256 K)
100 - 200 K	-	-	3 (192 K), 2 (128 K)
50 - 100 K	1	9 (50 K)	33 (50 K), 2 (80 K), 3 (72 K), 5 (56 K)
9.6 K	1	4	5

TABLE 3-1
BASELINE USER CHANNELS (CONT'D)

USER SIGNALS	LIGHT (MIST BASELINE)	MEDIUM	HEAVY
4.8 K	1	4	24
2.4 K	-	8	36
1.2 K	-	13	26
600	-	3	-
300	-	12	4
150	-	3	6
75	-	133	88
OTHER	-	2 (64 K)	10 (64 K)
			1 (32 K)
			1 (19.6 K)
			1 (7.2 K)
			2 (3.0 K)
			3 (1.8 K)
AGGREGATE RATE	6.24 MBPS	12.47 MBPS	37.46 MBPS
TOTAL USER SIGNALS	59	281	381

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TABLE 3-2
BASELINE EQUIPMENT COMPLEMENTS

EQUIPMENT	LIGHT (MIST BASELINE)	MEDIUM	HEAVY
ECCH R/T UNITS (AN/USC-28)	4	14	31
HIGH RATE (300 K-5 M) ECCH R/T UNIT	1	-	-
CODECS (KY-883)	5	24	67
NON-ECCH R/T (MD-1002)	4	9	33
ENCRYPTOR (KG-84)	2	13	14
SECURE VOICE UNITS (KY-71)	1	-	-
QUALITY MONITORS	8	≥ 19	≥ 44
DFCS CDL MODEM	1	1	1
MULTIPLEXERS			
LOW RATE MULTIPLEXER (LRM)	3	11	4
AN/FCC-98	2	12	16
AN/GSC-24	2	7	13

Communications connectivity within the terminal is best characterized by following a user circuit in the transmit direction from the main distribution frame to the IF patch panel. The user signal follows a circuit from the main distribution frame either directly to a modem (for high rate and some ECCM users) or to a group of multiplexers where it is combined with other signals to form a higher rate signal. This high rate signal is then routed either to another multiplexer or to a receive/transmit (R/T) unit of a modem. The data signal is error-correction coded and modulated to IF, then routed through the IF patch panel to an upconverter where it is allocated one of the satellite channels and transmitted at RF. Circuit switching in the DSCS network is currently accomplished by switching the user circuit, via manual patch panels, to an alternate multiplexer whose output is routed to the desired location. Switching of entire groups of circuits is accomplished by switching multiplexer outputs via the patch panel. In the event of an equipment failure, patch panels are also used to work around failed equipment.

Increased requirements for controllability, status monitoring and fault monitoring have created connectivity requirements between equipment and control and status monitoring capabilities in DSCS network terminals. In addition to communications connectivities, Figure 3-9 depicts typical equipment control and status connectivities. Underlying the connectivity for control and status signals in the terminals is the division of control and monitoring responsibility among the DSCS control subsystems, DECS, DFCS, FSM, etc. The DECS processor allows for control and status interfaces to the Low Rate Multiplexer, AN/USC-28 modem, KY-833 codecs and the terminal Fault Status Monitor (FSM). The DECS processor also allows secure communication of terminal control and status data over the Critical Control Circuits to the Network Control Terminals. The DFCS processor allows for interfaces to the FDMA modem, carrier monitor, a performance monitor (for PBER), the terminal fault status monitor, and also communicates to the central DFCS processor at the Network Control Terminal over the Control Data Link.

Much of the equipment currently installed in the earth terminals are not designed to interface with a central control and monitor system and as a result do not provide any standard control and monitoring access. For example, the multiplexers not mentioned above (FCC-98, GSC-24) currently provide relay switch alarms and are configurable from their front panel only. Multiplexer equipment currently being developed (e.g., IMPAT) do provide control and status interfaces which may be exploited for terminal monitoring (via the FSM) and configuration control. A control subsystem for these multiplexers, however, has not been identified. The MIST specification calls for a centralized control, monitor, and alarm subsystem whose interaction with DECS and DFCS is unclear. Similarly, the SAMT RF terminal contains a central processor which allows for control and status interfaces to baseband equipment which is not explicitly included in the SAMT.

The handling of classified data in the terminals is an issue which affects the interconnection of equipment. Communication connectivities, with the exception of the CCC and CDL lines, are assumed to be previously encrypted and considered black. Processors containing network configuration data; i.e., DECS, are considered red, while control and status connectivities to equipment may be black if they are properly protected with a Line Guardian Unit to prevent classified information from the processor from entering a black area.

SECTION 4

LOCAL AREA NETWORK OPTIONS

4.1 INTRODUCTION

This section serves to provide some background on local area networks and acts as a basis for this study's discussion of the use of LAN technology in DSCS earth terminals. A local area network may be broadly defined as the interconnection of communicating devices within a limited physical region, on the order of a few square kilometers. As a consequence of their role in the emergence of the "electronic office," local area networks are often associated with on-site packet-switched computer communications. Even that description, however, is overly restrictive given the wide variety of LAN designs that exist, both commercially and experimentally. The many variables involved may be seen in terms of the available local area network options of topology, transmission media, and access control techniques outlined in this section.

The diversity possible among local area networks, however, has lead to confusion in the marketplace. Appendix B tabulates a number of LAN manufacturers and their products, illustrating the many LAN technologies currently available. To promote coordination within the computer and communications industry, the IEEE 802 committee issued in July, 1981 its first draft of a proposed local network standard governing the two lowest layers of the OSI architecture. After several years of refinement, the standards have now been approved and adopted by many major equipment vendors. The US Department of Defense has also made efforts to standardize local area networks, one example being the Unified Local Area Network Architecture (ULANA) of the Air Force.

IEEE 802 Committee LAN Standards

The IEEE standards restrict themselves to local area networks where stations are on the order of one kilometer of each other and engaged in

IEEE 802 COMMITTEE LAN STANDARD DEVELOPMENT

- 802.1 802 COMMITTEE LAN STANDARDS AND THE OSI REFERENCE MODEL
- 802.2 LOGICAL LINK CONTROL
- 802.3 CSMA/CD ACCESS METHOD AND PHYSICAL LAYER SPECIFICATION
- 802.4 TOKEN-PASSING BUS ACCESS METHOD AND PHYSICAL LAYER SPECIFICATION
- 802.5 TOKEN-PASSING RING ACCESS METHOD AND PHYSICAL LAYER SPECIFICATION
- 802.6 METROPOLITAN AREA NETWORK ACCESS METHOD AND PHYSICAL LAYER
SPECIFICATION

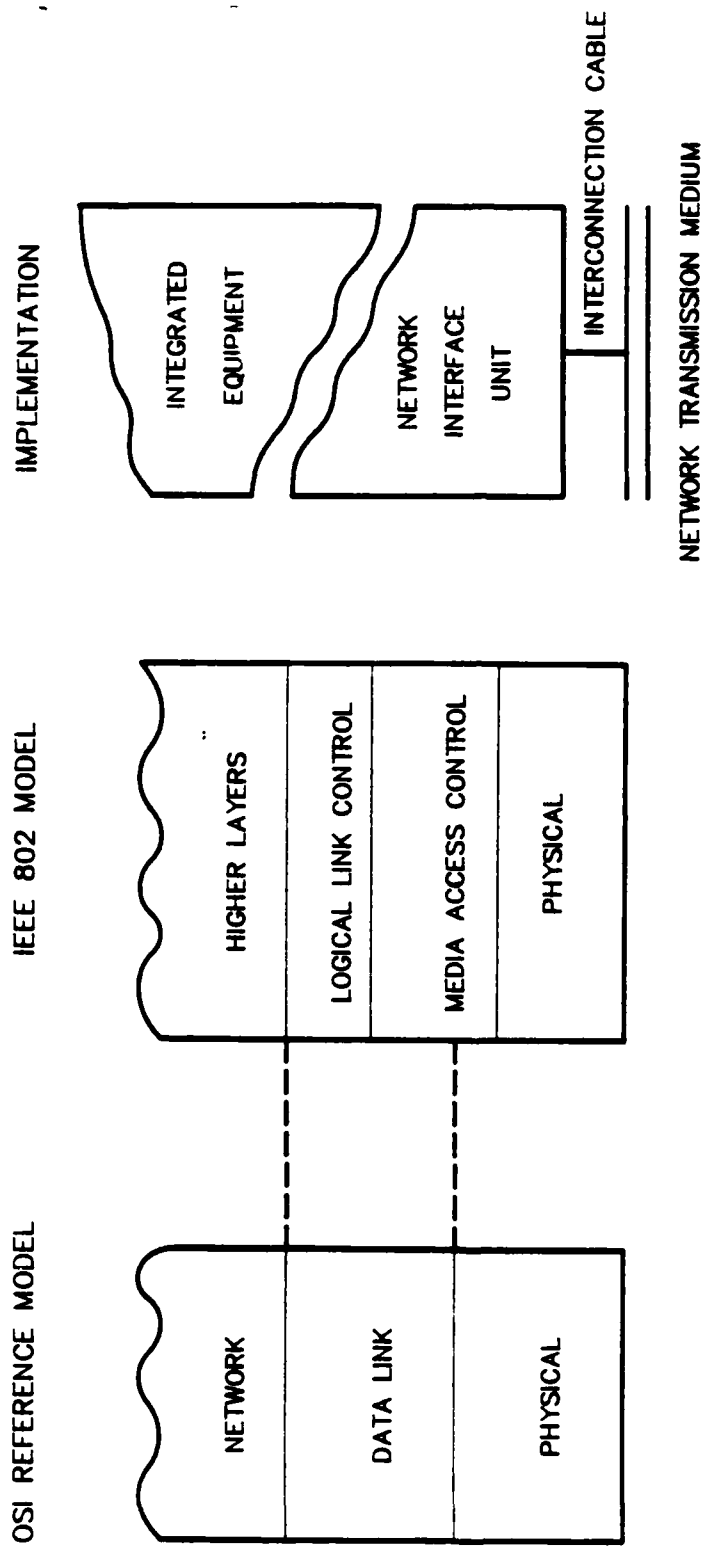


FIGURE 4-1: LOCAL AREA NETWORK INTERFACING

commercial or light industrial applications. The standards pointedly do not address issues such as computer-controlled voice/data Private Branch Exchange (PBX) networks, military local networks, and real-time, high reliability industrial applications such as process control. Nonetheless, the IEEE 802 committee's efforts in providing standards have allowed many manufacturers to move with confidence in presenting local area networks to the commercial marketplace.

The IEEE 802 committee LAN standards define a shared channel configuration, with low cost and ease of incremental network expansion considered to be design goals. The IEEE standard subdivides the OSI Data Link Layer into two layers, the Logical Link Control and Media Access Control Layers, as shown in Figure 4-1. The Logical Link Control layer draws upon the Asynchronous Balanced Mode link control procedures specified by ISO 6256-1979 and ANSI X3.66-1979 to define a standardized frame format and error recovery procedure. The Media Access Control Layer defines the mechanisms by which the shared channel is successfully utilized by the stations composing the network. Figure 4-1 illustrates how the responsibilities of the two IEEE 802 layers may be arbitrarily divided between the Network Interface unit and the attached device, depending on the capabilities of the device and the specific implementation. Since throughput and message delay characteristics are dependent upon the employed channel access protocol, the IEEE 802 committee has developed proposed standards for two access control techniques, token-passing and carrier sense multiple access with collision detection (CSMA-CD).

The IEEE specification also applies to the OSI Physical Layer and the physical medium itself (which is beyond the scope of the OSI Reference Model). Characteristics of a physical interface are thus defined which allow it to be independently implemented by different vendors and still prove compatible. Currently, the standards define specific functional, electrical, and mechanical characteristics of a baseband coaxial cable system supporting CSMA-CD and a coaxial cable system supporting a "token-passing single channel phase-continuous frequency shift keying (FSK) bus"; other media are to be standardized at some future date.

Air Force Unified Local Area Network Architecture

The Air Force Unified Local Area Network Architecture (ULANA) is a subset of the Air Force Information System Architecture (AFISA). The goal of the Information System Architecture is to provide a basis on which to guide both the near- and long-term design of individual and integrated information systems. In that context, ULANA is intended to provide the architecture and hardware/software needed to implement the Air Force's local area networks.

ULANA is meant to support information transfer among devices (as opposed to, say, process control). The ULANA architecture is therefore predicated on several design principles: 1), a layered architecture is observed, in the spirit of the OSI Reference Model and the DOD Protocol Reference Model; 2), ULANA is to be fully interoperable with the DOD long haul network, the Defense Data Network (DDN); and 3), almost all network communications functions are to be distributed in network interface units which interface and attach the subscriber devices to the local area network.

As a consequence of its goals and objectives, the ULANA effort concerns itself mostly with the interfacing of the local area network to subscriber devices and to external networks such as DDN or public packet-switching networks. The employed media access control techniques---the main concern of the IEEE 802 committee---are not a focus of ULANA, although their importance is recognized. ULANA thus attempts to standardize the Air Force's use of local area networks by defining and contracting standardized equipment.

Local Area Networks Versus Computer Buses

The broad definition of a local area network given above might also be taken to apply to the bus structure of a computer. Indeed, local area networks may possess a bus topology, yet such a network would not be considered a computer bus. The distinctions are perhaps subtle, hinging on the notion of a local area network as the interconnection of a number of autonomous stations.

The management and control strategies of a network, for example, are far more defensive than the equivalent strategies of a bus are required to be. Failure of a connected device on a computer bus structure generally leads to failure of the system; a network, however, should exhibit more fault-tolerant behavior. If insufficient capacity is available on a bus, hardware or software reconfigurations are typically necessary; a network will instead attempt to gracefully mediate such intense traffic demands. Local area networks are also more general than computer buses. A network usually supports the transmission of variable size messages, while a bus often handles only single, fixed-size words. The interfaces provided by a network are often generalized to accommodate a wide variety of devices; a computer bus typically has a specialized interface directed towards the addressing and control architecture of a particular device.

The bus structure defined by the IEEE-488 standard illustrates the distinctions between local area networks and computer buses. The IEEE-488 standard defines a general byte serial bit parallel interface capable of interconnecting a variety of instruments and computers and has been implemented in several brand versions as, for example, HP-IB, GPIB, and the IEEE Instrumentation Bus. The HP-IB provides a maximum supported data rate of 1 Mbps with the total transmission path lengths restricted to less than 20 meters or 2 meters per device, whichever is less. By interconnecting devices with such a level of autonomy, the IEEE-488 bus resembles a local area network. The bus does not, however, support more than 15 devices in one contiguous bus nor does its addressing structure readily allow it to be extended. Furthermore, the IEEE-488 bus is not as defensive as a local area network would be: the system designer must insure that the capacity of the bus is not exceeded and must detect and insure the removal of faulty connections which disable the bus. With such distinctions in mind, the design of a local area network involves consideration of various options concerning the network topology, transmission medium, and access control technique.

4.2 LOCAL AREA NETWORK TOPOLOGIES

The interconnection of devices in a local area network may be configured in several different topologies, as shown in Figure 4-2; bus, star, ring, and tree topologies are typical, although hybrids (mesh topologies) are possible. The choice of topology reflects various aspects of the network; for example, whether a central controller is present, whether there exists a logical hierarchy of network users, etc. The selection of network topology may also be intimately related to the choice of the network access control mechanism; indeed, the operation of some access protocols relies upon specific network organizations.

Local area network topologies may be divided into two main classes, broadcast and sequential. In a broadcast configuration, a transmission by one station is received by all stations of the network. In a sequential configuration, point-to-point transmissions between stations define the communications flow.

Broadcast topologies intrinsically require that each station transceiver be able to handle a wide range of signal strengths. A minimum signal strength on a broadcast topology is generally established by limiting both the length of the transmission media and the number of connections. If the network is to exceed these limits, amplifiers or repeaters are often used to maintain the necessary levels.

In a broadcast configuration, only one station may successfully use the channel at a time. Access control protocols must therefore regulate which station may assume control of the shared channel. The maximum end-to-end propagation delay of the broadcast channel imposes an implicit delay overhead, however, which is often on the order of hundreds of bit times. To minimize the impact of such overhead, broadcast local area networks typically specify a minimum packet size which may be transmitted.

LOCAL AREA NETWORK OPTIONS: TOPOLOGIES

- BUS
 - BROADCAST OPERATION WHEREIN A TRANSMISSION BY ONE STATION IS RECEIVED BY ALL STATIONS OF THE NETWORK
 - FAILURE OF A STATION DOES NOT AFFECT OPERATION OF NETWORK
- STAR
 - CENTRAL NODE LINKING ALL OTHER STATIONS
 - FAILURE OF CENTRAL NODE GENERALLY IMPLIES NETWORK FAILURE
- RING
 - SEQUENTIAL OPERATION, DATA RELAYED FROM STATION TO STATION
 - NETWORK REDUNDANCY REQUIRED TO REDUCE RISK OF NETWORK FAILURE UPON STATION FAILURE
- TREE: CENTRALIZED, DECENTRALIZED, OR HYBRID OPERATION
- HYBRID TOPOLOGIES

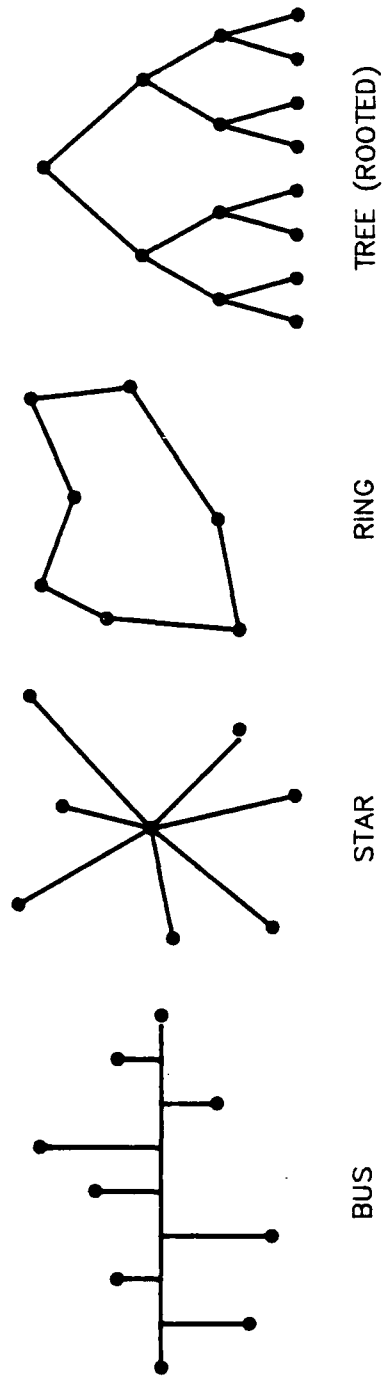


FIGURE 4-2: LAN TOPOLOGIES
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USE OF LAN(LOCAL AREA NETWORK) TECHNOLOGY IN DSCS
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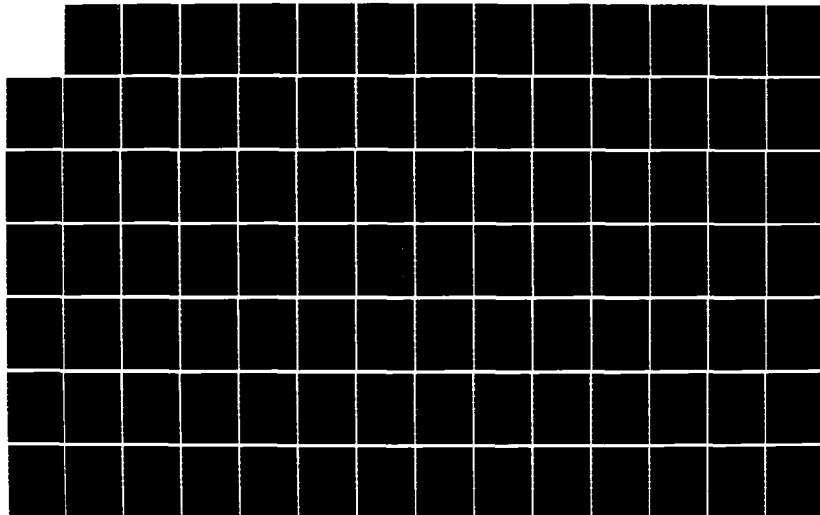
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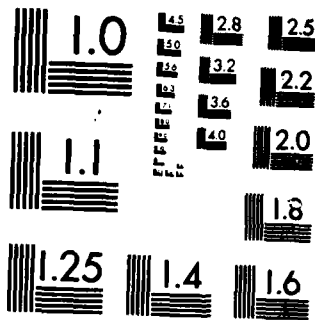
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Sequential configurations, as compared to broadcast configurations, do not place such stringent requirements on the performance of station transceivers since only point-to-point connections need be supported. Consequently, different transmission media between stations may even be employed to constitute the sequential network.

Bus

A bus topology implies a broadcast configuration and is one of the most common of local area network topologies. Bus topologies are characterized by standardized connection interfaces and high reliability. Typically, stations attach to the network transmission medium in such a way that the failure of any station will not affect operation of the network. In the case of coaxial cable bus networks, for example, stations may be attached to the cable with taps which do not require physically cutting the cable. A bus topology thus often implies a reliable network, unaffected by individual station failures. Physical damage to the bus, of course, will likely disrupt the network unless a duplicate bus is installed as backup.

A bus topology, however, does have several disadvantages. For example, every station must be able to send and receive data at the full speed of the bus, possibly a much greater data rate than is required. Every station must also transmit with enough signal power to be received at the most distant station. And since all network stations observe all network traffic, a bus is inherently non-secure; sensitive data must be encrypted or alternate transmission means must be provided for such data.

Tree

A tree configuration may be seen as the interconnection of several buses joined by active repeaters or by passive splitters. Such an extended bus effectively defines a rootless branching tree topology. In broadband coaxial cable local area networks, a rooted tree topology is often used where the root is defined by the cable's active head end. In such cases,

the tree is vulnerable to failure of the equipment at the root unless adequate redundancy is provided. A tree topology may also be used when some hierarchy among stations is to be established. Hierarchical groupings may be desired for purposes of the network itself (e.g., in order to implement the access control algorithm) or to reflect functional characteristics of the attached stations.

Star

A star topology implies a central node to which all other stations are linked; it may be seen as a rooted tree topology in which a branch extends from the root to all network stations. A central computer which cyclically polls all attached stations or a Private Branch Exchange (PBX) local area network are examples of such a topology. Failure of the central node, however, typically implies failure of the entire network unless provision is made for such a contingency. Additionally, if cabling is used to support a star topology local area network, then new cabling must be installed for every new station added to the network and, generally, much more cabling is required than in an equivalent bus or ring network.

Ring

In a ring topology, stations sequentially relay data from one to another, each station typically receiving, scanning, and regenerating signals on the ring. Reliability thus becomes a factor, since the failure of a single station may disrupt operation of the network. Multiple connections between stations may be used to provide a measure of redundancy, protecting against a limited number of station failures. Alternatively, fail-safe bypassing of faulty stations may be used to enhance reliability.

A ring topology also lends itself well to fully synchronous operation. At data rates below 1 Mbps, the asynchronous burst mode of operation supported by a bus topology provides reliable performance. At data rates above 10 Mbps, however, establishing the synchronization necessary for acceptable

probabilities of error on such a system becomes technically difficult. A synchronous, phase-locked ring system, on the other hand, readily achieves desired performance levels.

Hybrid Topologies

Local area networks have also been designed using mixes of the above topologies. For example, a star-shaped ring is possible in which the stations are arranged in a star configuration, connected by forward and return circuits to a central (passive or active) node. As another example, one of the Ungermann-Bass Net/One LAN configurations defines a network in which a tree topology interconnects multiplexers each of which supports a star of RS-232 cable connections to the attached terminals. Another Net/One configuration links coaxial cable buses via fiber-optic cable into a star network.

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4.3 LOCAL AREA NETWORK MEDIA

Many different types of transmission media may be used in local area networks; indeed, a single network may utilize a variety of media. The transmission media and limited physical size of a local area network permit bit error rates on the order of 10^{-9} . Such low error rates are in fact assumed in the operation of LAN Data Link Layer protocols. Media types include twisted pair (shielded and unshielded), baseband coaxial cable, broadband coaxial cable, fiber-optic cable, and even unguided media, e.g., line-of-sight RF signals.

Twisted Pair

Twisted wire pair is often chosen as the local area network medium in office environments where 22- or 24-gauge telephone installations are already present. Even if existing wires are not used, its low cost and ease of installation make twisted wire pair an attractive choice. High attenuation limits the bandwidth which it may support to data rates less than 9.6 kbps, however, and, if not shielded, twisted pair is prone to interference (crosstalk, noise, etc.).

Coaxial Cable

Coaxial cable, on the other hand, resists interference and supports a high bandwidth. Baseband coax may support up to 50 Mbps; broadband coax, by using Community Antenna Television (CATV) technology to provide multiple frequency division-multiplexed channels, may support up to 150-200 Mbps. Broadband cable networks are either single or dual cable systems supporting separate transmit and receive channels. In a dual cable system, one cable (or one segment of cable) defines the transmit channel while the other cable (or segment) defines the receive channel; in a single cable system, the usable bandwidth is split into transmit and receive channels.

LOCAL AREA NETWORK OPTIONS: MEDIA

- TWISTED-PAIR WIRE
 - INEXPENSIVE
 - DATA RATES 300 BPS - 9.6 KBPS ARE TYPICAL
- COAXIAL CABLE
 - BASEBAND: DATA RATES ~ 50 MBPS
 - BROADBAND: DATA RATES ~ 200 MBPS
- FIBER-OPTIC CABLE
 - RFI/EMI IMMUNITY
 - DATA RATES ABOVE ~ 500 MBPS
- UNBOUNDED MEDIA
 - RADIO
 - MICROWAVE
 - INFRARED
- HYBRID SYSTEMS

Broadband cable systems define a rooted tree topology, the root of the tree commonly termed the head end. In a single cable network, the head end includes a frequency shifter to re-broadcast in the receive frequency band the signals received on the transmit band. Frequency shifters are also found in some dual cable systems in order to reduce the problem of crosstalk in the station modems. Alternatively, a dual cable system may have a completely passive head end simply by bending the transmit cable and routing it again to the attached stations as the receive cable.

Costs of a broadband coaxial cable system are typically higher than that of an equivalent baseband system as a result of the filters and RF modems that are required. The extended bandwidth, however, allows high data rates and permits the use of frequency division multiplexing as a means of sharing channel capacity among the network stations.

Fiber-Optic Cable

As a transmission medium, fiber-optic cable affords numerous advantages. Since it is an all-dielectric medium, it exhibits RFI and EMI immunity, allowing installation in high-voltage environments as may be present in possible industrial applications. Conversely, fiber-optic cable provides a secure transmission medium with little or no leakage of signal radiation. The cable's small size, low attenuation, and high bandwidth (capable of supporting rates even above 1 Gbps, although typically on the order of several hundred Mbps) allow more efficient use of available conduit or duct space.

Due to the characteristics of laser sources and the consequent non-linearity in the transformation from electric to optical signals, less efficient modulation schemes must be used in a fiber optic system than in a coaxial system. Several times more bandwidth on a fiber-optic cable are thus required to transmit the same number of channels as on a coaxial system. The large bandwidth capacity of fiber optics, however, still allows many more equivalent channels than may be supported on coaxial

cable. Typical multiplexing techniques for use with fiber-optic cabling are: 1) time-division multiplexing (TDM) combined with Pulse Code Modulation (PCM) signalling; 2) frequency-division multiplexing (FDM) using analog frequency modulation (FM); and 3) wavelength-division multiplexing (WDM) of baseband amplitude modulated (AM) optical signals.

Interfaces to optical fiber transmission media are through either active or passive devices. Active couplers receive all of the optic fiber's optical signal energy and, since true optical-to-optical repeaters are not yet available, perform opto-electrical conversion, signal regeneration and insertion, and then electro-optical conversion for retransmission on the medium; passive interfaces provide optical-to-optical coupling, receiving a fraction of the fiber's optical energy and/or injecting optical energy directly into the cable. Interface costs, electronic complexity, and reliability concerns are drawbacks to use of active devices; the power losses and distortions associated with optical-to-optical passive coupling impose limits to the number of network interfaces if network power budgets are to be satisfied.

Indeed, use of fiber-optic cable in passive bus or ring configurations is not practical since current coupler technology severely limits the number that may be employed in sequence, often to less than twenty in typical such systems. Manufacturers have instead implemented fiber-optic versions of bus or ring networks by employing active devices and/or effectively collapsing the "bus" or "ring" to a single point, creating a star topology. Hybrid interfaces are sometimes used to provide a fail-safe coupling: if the active regenerating unit fails, the passive coupling remains intact.

Unbounded Media

The use of unbounded media in local area networks avoids the need of cable installation and provides flexibility in the location of network

stations. Two approaches have been used to implement such wireless indoor communications: use of infrared radiation or use of spread-spectrum microwave technology.

In indoor applications, infrared radiation (IR) does not interfere with existing RF systems and, since it is essentially restricted to the room in which it is generated, cannot be detected outside that room and will not interfere with nearby systems in different rooms. Data transmission rates as supported by IR systems are limited by the effects of multipath, ambient light, and the transient times of the employed light-emitting diodes (LED's). Assuming ambient light to be restricted in the facility, data rates are effectively limited by the LED rise and fall times; for the Siemens LD-271 or Gilway-E14 LED's, for example, this limitation is on the order of 500 kbps. In experimental IR systems, however, lower data rates have typically been achieved. Due to the multipath environment which IR communications are subjected, digital communications are best effected if carrier synchronization is avoided, suggesting use of non-coherent communications techniques such as non-coherent FSK or differentially coherent phase shift keying (PSK).

To counteract the effects of multipath and frequency selective fading in closed environments, spread-spectrum RF or IR signals may be used, additionally reducing the possibilities of interference and detectability. Furthermore, shared utilization of a given channel bandwidth may be accomplished through code-division multiple-access (CDMA). In a decentralized system, however, use of spread-spectrum techniques involves considerable expense.

Unbounded media have not, however, been popular choices for the designers of local area networks. Spatial limitations, security worries, and cheaper and more available alternatives have restricted the usage of unbounded media.

4.4 LOCAL AREA NETWORK ACCESS CONTROL TECHNIQUES

While the network topology defines the connectivity of the network, the flow of communications among stations is regulated by the network's employed access control protocol. The development of local area networks has been spurred by the need to support computer communications. To efficiently accommodate the bursty generation of traffic typical of such communications, local area networks generally provide packet- or message-switched services over a shared communications resource. Three basic channel access strategies are possible as shown in Figure 4-3: reservation, selection, and random access. And, depending on the details of the particular access control technique, implementation of the control strategy is either through centralized control of network communications or by use of distributed, decentralized control.

Centralized Versus Distributed Access Control

Centralized control of a local area network implies the presence of a network controller coordinating network communications; in a decentralized network, the intelligence to coordinate network communications is provided by each of the attached stations.

In a centralized network, the central controller administers the flow of communications on the network. Typically, an individual station's responsibility is to respond to a network condition or an explicit query and at that time gain access to the channel; coordination of these activities is the role of the central controller. The failure of the central controller generally implies failure of the network. Often, however, centralized control is employed in networks where the attached stations are subordinate to a central processor which, additionally, serves as network controller. In such systems, continued functioning of the network in the event of failure of the central processor is probably of no use anyway.

Either form of network control, centralized or distributed, may generally be employed in an arbitrary network, but distributed control perhaps most suits those networks composed of autonomous devices engaged in peer-to-peer communications. In such cases, the processing power needed to administer network control is presumably readily available. On the other hand, if an attached device does not possess the needed processing capabilities, then the required network intelligence must be provided by that station's interface unit. By distributing access control responsibilities in this manner, network reliability is typically enhanced.

Reservation Access Control Techniques

In reservation techniques of channel access control, a station transmits a data packet according to a predetermined allocation of channel capacity. Once channel capacity is reserved for a particular station, no further external coordination or control is needed to permit that station to access the shared channel. Channel capacity is typically shared through time division multiple access (TDMA): capacity is allocated by granting a station an individual slot of time long enough for the transmission of one message/packet. Frequency division multiple access (FDMA) and code division multiple access schemes may also be seen as reservation techniques, but neither scheme is often used in local area networks since the resultant circuit-switched capability is generally inappropriate for bursty computer communications.

Channel capacity may be reserved in a static or dynamic fashion. Static assignments of capacity may lead to under-utilization of the channel, hence the desirability of a dynamic reservation scheme. Centralized control is typically used in TDMA reservation access techniques in order to establish synchronization among the stations of the network. In typical dynamic reservation schemes, a centralized controller dynamically allocates channel capacity on the basis of station requests for access. Asynchronous time division multiple access, also known as statistical multiplexing, is an example of such a dynamic reservation technique. Distributed control

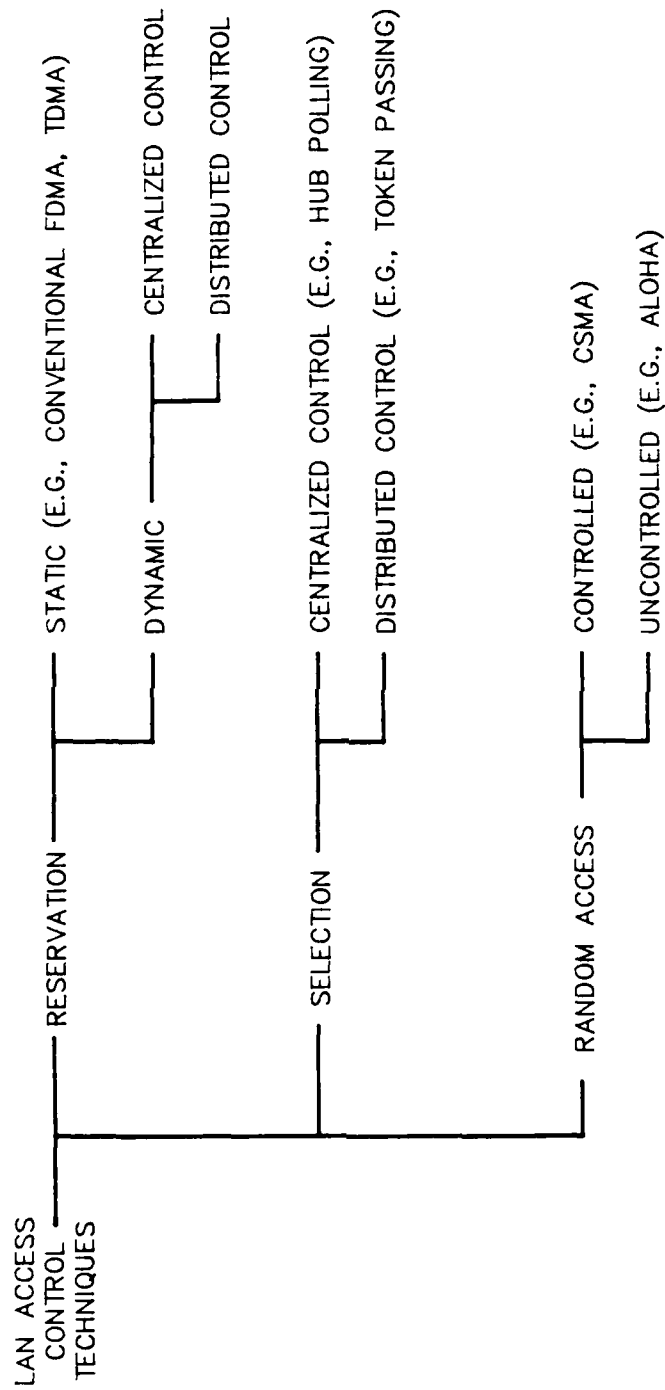


FIGURE 4-3: LOCAL AREA NETWORK ACCESS
CONTROL TECHNIQUES

dynamic reservation techniques are also possible, although these have generally been proposed for the access control of satellite channels rather than for local area networks.

Selection Access Control Techniques

Selection protocols, rather than reserving capacity, effectively choose which users may access the channel at a given time. A station may only access the channel when it has been appropriately signalled ("selected"); before selection, the station must buffer all data to be transmitted until access is granted. Selection techniques may be implemented using either centralized or distributed control.

With centralized control, the signals prompting a station to transmit on the shared channel are generated by a central channel controller. In roll-call polling systems, for example, the central controller addresses the network stations one at a time; stations with message packets to transmit do so only upon being polled. The sequence in which stations are polled may be either fixed or variable; indeed, priorities among stations may be established by polling particular stations multiple times within a single polling cycle. Other versions of centralized selection access control involve use of a control channel to either signal stations that they may access the shared channel ("daisy chaining") and/or allow stations to independently request channel access from the central controller.

Decentralized selection access techniques are also possible, one such technique, token passing, being among the standards proposed by the IEEE 802 committee. In token passing systems, access control is regulated through possession of the "token," a token typically being control bits within a data frame. If the station with the token has data to transmit, it sends its data and then passes the token to the next station. If the station has no data to transmit, it passes the token immediately. Stations receive the token in sequence, thereby establishing a maximum time which a station must wait in order to access the channel. The sequential granting

of access characteristic of token passing makes this technique very appropriate for sequential media and ring topologies, resulting in the "token ring." The sequential passing of control may also be constructed logically on broadcast media, hence the "token bus." Furthermore, priority schemes may be implemented by only allowing those stations with the highest priority to access the channel every time the token is received.

Random Access Control Techniques

Random access control techniques attempt to provide channel access to stations upon demand. A station must either wait to be granted access in a selection system or must wait for its pre-arranged access in a reservation system---in a random access system, a station may ideally access the channel at any time. By definition, then, control of a random access system is distributed. Uncontrolled or controlled random access techniques are possible, although the archetypical uncontrolled random access technique, pure ALOHA, is known more for historic and academic than practical significance. In controlled random access systems, stations are not "deaf" but possess some knowledge of channel activity.

The best known example of a random access control protocol is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). Implemented by DEC/Intel/Xerox as "Ethernet", the CSMA/CD algorithm has been standardized by the IEEE 802 committee.

The CSMA/CD technique defined by DEC/Intel/Xerox and the 802 committee is but one variation of the many possible carrier sense multiple access techniques in which stations monitor activity on a shared broadcast channel and attempt transmission when the channel is sensed idle. The CSMA/CD algorithm of Ethernet and the 802 committee is known in the research literature as 1-persistent CSMA/CD. In this algorithm, stations with a data packet (frame) ready to transmit sense the channel before beginning their transmission. If the channel is sensed idle, transmission begins; if sensed busy, transmission is deferred until the channel is again sensed

idle. At that time, transmission is again attempted after a fixed duration interframe gap used to allow the transceivers and channel to stabilize between transmissions. Transmission is attempted regardless of whether the channel is sensed idle or busy. It is this behavior upon deferring transmission which is termed 1-persistent: after deferring its transmission, a station persists in its attempt, trying again with probability one. Contrast this response to that of p-persistent CSMA, which transmits after deferral with probability p. In non-persistent CSMA, on the other hand, a station treats a deferral as if a collision had occurred.

Due to propagation delays on the shared channel, two or more stations may sense the channel idle and attempt concurrent transmissions, resulting in a collision on the broadcast channel. Such collisions are detected by the colliding stations who then continue their transmission for a fixed number of bits, jamming the channel to insure that all stations sense the channel as busy. Retransmission is scheduled according to the value determined by "truncated binary exponential backoff:" a delay of r slot times is observed---one slot equaling a fixed number of bit-times---before the n -th retransmission attempts. The value of r is chosen as a uniformly distributed random integer in the range of $0 \leq r < 2k$, where k is either the number of retransmission attempts, n , or some predetermined backoff limit, whichever is smaller. Some degree of prioritization among stations is possible by different assignments of scheduling delays, but this technique is not specifically part of the 802 committee specifications. Transmission is attempted a limited total number of times; if all allowed attempts fail, the attempt is abandoned and an error is reported to higher protocol layers.

The parameter of slot time mentioned above is not just arbitrarily selected. The slot time, the unit of time used in scheduling retransmissions, must be an upper bound on the acquisition time of the medium and on the length of the frame fragment generated by a collision. Clearly, the slot time is determined by the network implementation: it

must be larger than the sum of the maximum network round-trip propagation time and jam time. The parameter values specified by the 802 committee and DEC/Intel/Xerox---the minimum and maximum frame sizes, the jam size, the maximum network configuration, the backoff limit, transmission media characteristics, transmission rate, interframe gap size, etc.---effectively fine-tune the CSMA/CD algorithm to realize optimal performance.

The CSMA/CD algorithm, of course, is a random access technique and so exhibits probabilistic delay performance. In certain applications such as local area network behavior may not be acceptable, requiring instead use of a selection or reservation technique. On the other hand, adaptive access control techniques have been researched which exhibit the qualities of random access schemes at low traffic levels and, in the presence of higher loads, of reservation or selection access techniques. While such techniques are not presently under consideration by the 802 committee, they do hold promise for future networks.

4.5 LAN ACCESS PROTOCOL PERFORMANCE CRITERIA

Local area networks are employed to satisfy specific communications needs; their performance must therefore be assessed with regard to the fulfillment of those needs. The distinctive characteristic of a local area network, however, is the shared utilization of a common channel. Comparison of local area networks, then, is often based on the relative performance capabilities of the employed access control technique.

Performance of an access protocol depends on the density of traffic that is supported. To quantify the demands made on the communications capability of a local area network, one speaks of the traffic intensity or load. Load is defined as the sum over all of the network stations of the product of the mean arrival rate (in frames per second) and the mean frame size (in seconds) for each individual station. Note that the definition of load implicitly considers the network transmission rate. On a shared channel, a load of unity represents a demand for the full network capacity; loads greater than unity may, of course, be presented to the network by the connected stations, but a shared channel cannot physically provide such service without degraded network performance. In star networks and some ring systems, however, traffic may flow independently between neighboring stations, allowing network loads greater than unity to be fully supported. Measurements of operational local area networks indicate that average traffic loads are typically much less than maximum, but instantaneous loads may reach high levels. As a function of load, then, the following indicators provide a measure of access control performance: throughput, delay, queue size, rejection rate, and failure rate. Of these performance indicators, throughput and delay are the most important.

Throughput

Throughput, as opposed to data rate or transmission rate, refers to the fraction of time which the system is successfully being utilized. A distinction is sometimes made between network throughput and data

LAN ACCESS PROTOCOL PERFORMANCE CRITERIA

- **LOAD: TRAFFIC INTENSITY TO BE SUPPORTED BY NETWORK**
- **THROUGHPUT: FRACTION OF TIME THE NETWORK IS SUCCESSFULLY UTILIZED**
 - NETWORK THROUGHPUT
 - DATA THROUGHPUT
- **DELAY: INTERVAL BETWEEN TRANSMISSION REQUEST AND SUCCESSFUL TRANSMISSION**
 - SELECTION AND RESERVATION PROTOCOLS
 - INVOLVE DELAY OVERHEADS AT ALL LOAD LEVELS
 - PROVIDE LIMITED PACKET DELAYS UNDER HEAVIEST LOADING
 - RANDOM ACCESS PROTOCOLS
 - PACKET DELAYS INCREASE WITH TRAFFIC INTENSITY
 - REDUCED DELAY OVERHEAD FOR LIGHT LOADS
- **QUEUE SIZE**
- **REJECTION RATE**
- **FAILURE RATE: RANDOM ACCESS PROTOCOLS ONLY**

throughput. Network throughput considers the fraction of time which the system is successfully transmitting data, including all overhead information; data throughput, on the other hand, does not include the time spent in transmitting overhead information and thus reflects only that fraction of the channel capacity used to transmit the ultimately desired data. Overhead in the sense used here refers to those portions of each data frame required by the various protocol layers for their proper operation. Such overhead may be in the form of data preambles for synchronization purposes, source and destination addresses, cyclic redundancy check codes used for error-checking, frame delimiters, etc. or may be manifest as additional channel traffic generated as part of normal network operation (data frames, for example, acknowledging a correctly received packet). To avoid consideration of all the possible aspects of data overhead, most discussions of LAN performance consider only network throughput.

Network throughput is very much a function of the access control protocol employed by the local area network. For example, computer simulation of a local area network using CSMA/CD as specified by the IEEE 802 committee reveals that network throughput typically equals the load up to a level of approximately .5. At loads greater than .5, network throughput somewhat lags behind the increased demand of network resources as a consequence of collisions and the contention resolution process, reaching a maximum level of approximately .95. Such performance represents almost complete utilization of the channel capacity, but other network performance suffers.

Delay

Besides throughput, the most important indicator of a network's performance is the delay a frame incurs from the time transmission is requested until successful transmission is finally accomplished. At high load levels, individual data packets suffer relatively greater delays in return for high system throughput. Excessive delays may limit the utility of the network and impede operation of individual users. The transmission of digitized

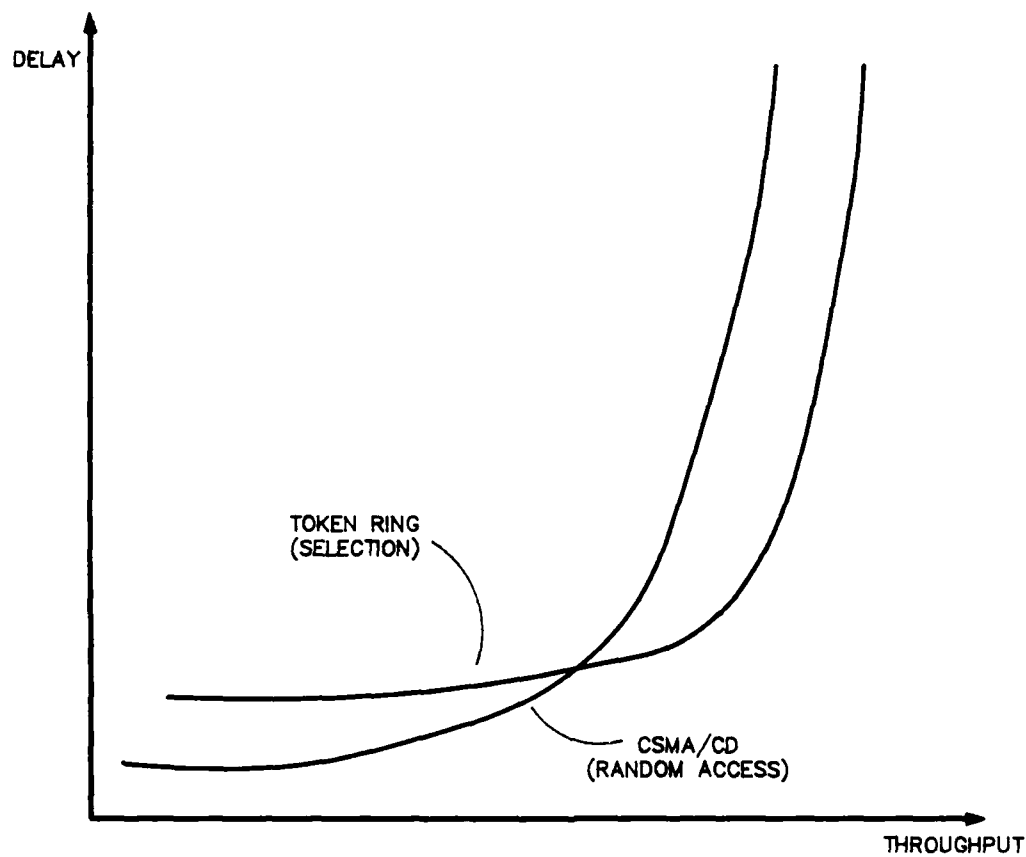


FIGURE 4-4: TYPICAL DELAY vs.
THROUGHPUT PERFORMANCE

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voice packets, for example, cannot be successfully supported when lengthy delays prohibit real-time re-assembly of the packets.

Delays may be intrinsic to the operation of the access control technique; for example, when a station must wait to be selected or must wait for its reserved channel slot before transmitting. Such delay overhead is a major aspect of selection and reservation techniques, although the overhead may be insignificant for performance at high traffic levels. At low traffic levels, however, the delay overhead involved in reservation or selection multiaccess protocols typically exceeds that incurred by random access protocols. Figure 4-4 provides a representative example of the delay-throughput tradeoff involved in selection, reservation, and random access schemes. The implementation of a system may also incur delay. For example, data packets awaiting transmission at each station are typically buffered. Intuitively, one expects a frame's mean waiting time to be sensitive to the buffer size of each station: as longer queues are allowed by a greater buffer capacity, the waiting times in those queues should consequently increase.

Queue Size, Rejection Rate, and Failure Rate

Other performance indicators besides throughput and delay are significant, although not often considered in the assessment of access control technique performance.

Queue size, as mentioned above, refers to the buffering of data frames ready for transmission. Queue size at any one station reflects both network performance (i.e., how efficiently media access is granted) and the particular frame generation rate at that station. For example, the queue size of two different stations with the same message generation rate on two different but comparable networks will most likely be approximately identical until fairly high arrival rates are reached. At that point, if the network load levels are different, the network performance in servicing frames in each station's buffer---a function of load, not frame generation rate---begins to be the major factor affecting queue size.

The most serious impact of a station's buffer size is demonstrated by the rejection rate, the rate at which frames are turned away from full station buffers. A non-zero rejection rate represents the failure of the access protocol and the station buffers to accommodate the offered load. Like queue size, the rejection rate can be expected to depend not just on system load, but also on the arrival rate of frames to each station.

The failure rate refers to the rate at which data frames fail to gain access to the channel in the required number of attempts. In terms of the OSI Reference Model, the failure is on the part of the data link layer and must be reported to higher protocol layers for appropriate action. Such media access failure is generally only possible for random access control techniques; in reservation or selection systems the delivery of a data frame is ultimately guaranteed, barring other types of failure. This behavior thus defines the trade-offs typically involved in using a random access technique: in return for reduced waiting times at low load levels, performance at high loads may be subject to such failures to achieve channel access.

SECTION 5

APPLICATION OF LAN TECHNOLOGY TO DSCS SUBSYSTEM INTEGRATION

5.1 INTRODUCTION

The interconnection of DSCS terminal devices involves the support of two types of intercommunications: the communication flows between devices in support of DSCS user communications and the flow of equipment control and status signals within the terminal.

The concepts presented here reflect four specific LAN design goals:

- functionality;
- flexibility;
- reliability; and,
- moderate cost.

Any proposed LAN design must fully address the system communication needs. Moreover, in fulfilling those needs the design should exhibit a high degree of modularity to foster efficient production, installation, and maintenance. Complexity is to be avoided in order to guarantee the reliability of the local area network---the functioning of the DSCS terminal must not be compromised by failure of the terminal's local area network. Future growth of any DSCS terminal facility must not be restricted by the local area network design---the LAN must allow for expansion. And, finally, the development and production costs of the local area network should not be excessive. The application of local area network technology to satisfy these goals in DSCS earth terminals leads to two distinct design approaches.

The first approach addresses both types of DSCS terminal intercommunications. A full intercommunications LAN is envisioned which will support both the control and status signal flows and also the dedicated DSCS user channels within an earth terminal. The high aggregate data rates and the need for dedicated reliable service lead to a fairly specific design concept.

If the interconnection of terminal devices needed to support the DSCS satellite circuits is accomplished through some other means (e.g., by manual patching as is currently employed or, perhaps, by some application of digital switching technology as suggested in Section 6 of this report), then a local area network may be used to handle only the data traffic generated by control and status monitoring functions. Such a control and status LAN may be implemented in a variety of ways, as will be discussed.

APPLICATION OF LAN TECHNOLOGY TO DSCS SUBSYSTEM INTEGRATION

● FULL INTERCOMMUNICATIONS LAN

- INTRODUCTION
- REPRESENTATIVE DESIGN CONCEPT
- NETWORK INTERFACE UNITS
- LAN MANAGEMENT
- CLASSIFIED/UNCLASSIFIED DATA
- LAN ACCESS AND TERMINAL CONFIGURATIONS
- RELIABILITY AND COST
- OBSERVATIONS

● CONTROL AND STATUS LAN

- INTRODUCTION
- CONNECTIVITY STRATEGIES
- CONSIDERATIONS
- CLASSIFIED/UNCLASSIFIED DATA
- OBSERVATIONS

5.2 FULL INTERCOMMUNICATIONS LAN

Introduction

A full terminal intercommunications LAN must provide three distinct capabilities:

- the local area network must support the signal interconnection of the various terminal components and subsystems;
- the local area network must provide a means of configuration control, allowing interconnections to be made and broken upon command; and,
- the local area network must provide for the communication of equipment control and status signals.

To support full terminal intercommunications and maintain transparency to DSCS users, a local area network capable of providing circuit-switched communications is necessary---packetization of user communications solely for intra-terminal communications would introduce unwanted complexity. Furthermore, while DSCS terminals support aggregate user data rates ranging from, say, 5 to 30 Mbps, as discussed in Section 3, the local area network must provide a dedicated channel between each equipment pair in the equipment chains supporting the user communications signals. As a consequence, the capacity of a terminal's full intercommunication LAN must be some factor greater than the supported aggregate user data rate. Since the earth terminal throughputs discussed in Section 3 presume full duplex communications, a full intercommunications LAN must support at least twice the indicated aggregate user data rates. The above functional requirements alone lead to the elimination of many of the possible local area network options, as indicated in Table 5-1: the need to provide dedicated channels disallows the use of selection or random access protocols; the required capacity eliminates all but fiber-optic or broadband coaxial cable or unbounded media from consideration.

FULL INTERCOMMUNICATIONS LAN: INTRODUCTION

- SUPPORTS INTERCONNECTION OF DEVICES FOR RELAY OF USER COMMUNICATIONS THROUGH DSCS EARTH TERMINAL

- SUPPORTS INTERCOMMUNICATION OF CONTROL AND STATUS SIGNALS BETWEEN DSCS TERMINAL EQUIPMENT AND CONTROL/STATUS MONITOR PROCESSOR(S)

The DSCS full intercommunications LAN conceived here, then, must be a broadband network with access controlled by a reservation scheme. Of all the possible topologies, a bus is the most appropriate, providing a reliable local area network without implicitly favoring any of the attached stations. Other topologies could be successfully implemented, of course, but none reliably suits the DSCS terminal connectivities and need for dedicated channels as well as a bus.

Of the three possible media choices, broadband coaxial cable is the most mature technology and hence the most conservative alternative; as such, it may be an appropriate choice for DSCS applications. The support of a local area network by radio frequency transmission poses RFI and security concerns, while the use of IR transceivers raises issues surrounding the development costs of high data rate devices and the need for special care in their installation. Optical fiber could certainly provide the needed bandwidth for a full intercommunications LAN, but current technology does not provide reliability and performance on the level of broadband coaxial cable. Fiber-optic cable used in a bus topology using passive devices, for example, imposes limits to the number of connections and the extent of the local area network as a result of the insertion losses imposed by each attached device; use of active devices in a bus configuration is possible, but reliability of the LAN then becomes a concern unless a fail-safe design is employed. Finally, current technology limits the dynamic range of optical receivers to approximately 25 dB over 250 MHz; such performance may be inadequate for the purposes of the full intercommunication LAN which must handle analog as well as digital signals.

To elucidate issues concerning the use and development of a full intercommunications LAN appropriate to DSCS terminals, a specific example of a design is considered in the following subsections. A broadband coaxial bus using frequency division multiple access (FDMA) and similar to the Shipboard Communications Area Network (SCAN) developed by the Department of the Navy is described. Other reservation access control

TABLE 5-1

FULL INTERCOMMUNICATIONS LAN: OPTIONS

<u>OPTIONS</u>		<u>COMMENTS</u>
TOPOLOGY	RING	INAPPROPRIATE CONNECTIVITY
	BUS	✓
	TREE	INAPPROPRIATE CONNECTIVITY
	STAR	INAPPROPRIATE CONNECTIVITY, UNRELIABLE
MEDIUM	FIBER-OPTIC	✓
	BASEBAND COAX	INSUFFICIENT BANDWIDTH
	BROADBAND COAX	✓
	TWISTED PAIR	INSUFFICIENT BANDWIDTH
ACCESS TECHNIQUE	UNBOUNDED MEDIA	DEVELOPMENT COSTS, RFI
	RESERVATION	✓
	SELECTION	DOES NOT PROVIDE DEDICATED CHANNELS
	RANDOM ACCESS	DOES NOT PROVIDE DEDICATED CHANNELS

schemes besides FDMA might also be used, but for illustrative purposes FDMA suffices in demonstrating the concepts needed to support full terminal intercommunications. Use of TDMA or, more appropriately, ATDMA would also be a possible approach, but such systems assume that all communications are digital and are typically centralized, dependent upon reliable operation of the central node for proper LAN performance---by contrast, the local area network described here, like SCAN, implements the FDMA access control protocol in a decentralized fashion.

Indeed, the SCAN system may be sufficiently flexible that the local area network detailed here might take advantage of equipment developed for SCAN. SCAN has also served as the model for the Data Bus of the Defense Communications Agency's Modular Building-Block concept. In that application, however, the bandwidths of the channels are not as wide as required to support the full earth terminal intercommunications under discussion here.

Representative Design Concept

The previous discussion has indicated the generic capabilities which a full intercommunications LAN must provide in order to satisfy the communications requirements; the following example allows various design issues and considerations to be explored. As a representative implementation, then, the DSCS full intercommunications LAN may be conceived as a broadband bus supported by coaxial cable and using frequency division multiplexing to achieve circuit-switching capabilities.

By establishing frequency division multiplexed channels on the broadband network, dedicated circuit-switched channels, both digital and analog, between terminal equipment may be maintained---separate and distinct frequency channels on the local area network define the connectivity between attached devices. Appendix C provides estimates of the interconnections involved in the baseline light, medium, and heavy terminals, classifying the connections in terms of the associated data

rates. These connections are full duplex, however, meaning that 2 channels are required for every one indicated in Tables C-1 through C-4. Arbitrary channels are assumed in those tables which are capable of supporting the actual data rates. Thus, for example, the heavy terminal requires approximately 4 channels (2 duplex channels) supporting as much as 8 Mbps, 16 channels at 2 Mbps, 6 channels at 1 Mbps, 12 channels at 500 kbps, 28 channels at 64 kbps, and 2 channels at 1 kbps. These numbers indicate that, in order to support these interconnections, the LAN must provide 62 dedicated channels (31 duplex channels) with a total capacity of:

$$(4 \times 8) + (16 \times 2) + (6 \times 1) + (12 \times .5) + (28 \times .064) + (2 \times .001) = 77.8 \text{ Mbps.}$$

Other channels would be required to interconnect redundant equipment and to connect those user circuits which involve no multiplexing but are routed directly to a modem. If user connections to the multiplexers are supported by the full intercommunications LAN---an issue discussed in a succeeding subsection---then the channels specified in Table 3-1 of Section 3.5 must also be supported. For the baseline heavy terminal, 381 duplex user channels provide a throughput of 37.46 Mbps, indicating that 762 full intercommunications LAN channels are needed, supporting 74.92 Mbps. The full intercommunications LAN for a heavy terminal must thus support either ~80 Mbps or, if user circuits are directly linked to the LAN, a total of ~155 Mbps. Guard bands between channels will also be necessary, further utilizing local area network bandwidth, but, even so, these rough calculations demonstrate that a broadband coaxial cable LAN can be used to support the terminal throughput. The actual channel allocations and bandwidths, of course, must be defined more rigorously if such an FDMA broadband LAN is to be implemented.

An additional channel (or channels) may be used to support the communications of local area network control signals and control and status data between DSCS terminal equipment and the controlling/monitoring processor(s). The bandwidth provided by coaxial cable readily allows dedicated circuit-switched channels to be allocated for each of the low

data rate control and status signal flows, but a more efficient use of channel capacity may be realized if all control and status signals are transmitted via packet-switching on the same channel. Control of the local area network itself---specifically, the allocation and re-allocation of channels---may similarly be co-ordinated in a packet-switched manner on the equipment control and status channel or on a separate LAN control channel.

The envisioned full intercommunications LAN would not support the interconnection of terminal signals at IF: routing of signals between the IF patch panel and the terminal RF subsystems would be accomplished in the current manner without benefit of the LAN. If, on the other hand, IF signals were to be relayed by the local area network, the required complexity of the network interface units would be considerably increased. The full intercommunications LAN would, as one of its functions, support the intercommunication of control and status signals among terminal devices, including those from the various RF subsystems and equipment. The communication of all equipment control and status signals via a local area network as suggested here, however, reflects aspects of how the control and status monitoring functions are accomplished---such issues are discussed in Section 5.3 concerning the control and status LAN.

Figure 5-1 illustrates how terminal devices would connect through network interface units to the broadband coaxial cable. A semi-rigid cable may be used as the LAN trunk with connections between the trunk and network interface units made by flexible drop coaxial cables. A passive dual cable approach using directional couplers increases reliability by avoiding the active frequency-translating head ends often used in broadband coaxial systems. Each piece of LAN-supported equipment connects to a network interface unit which, in turn, connects to the transmit and receive legs of the dual cable system.

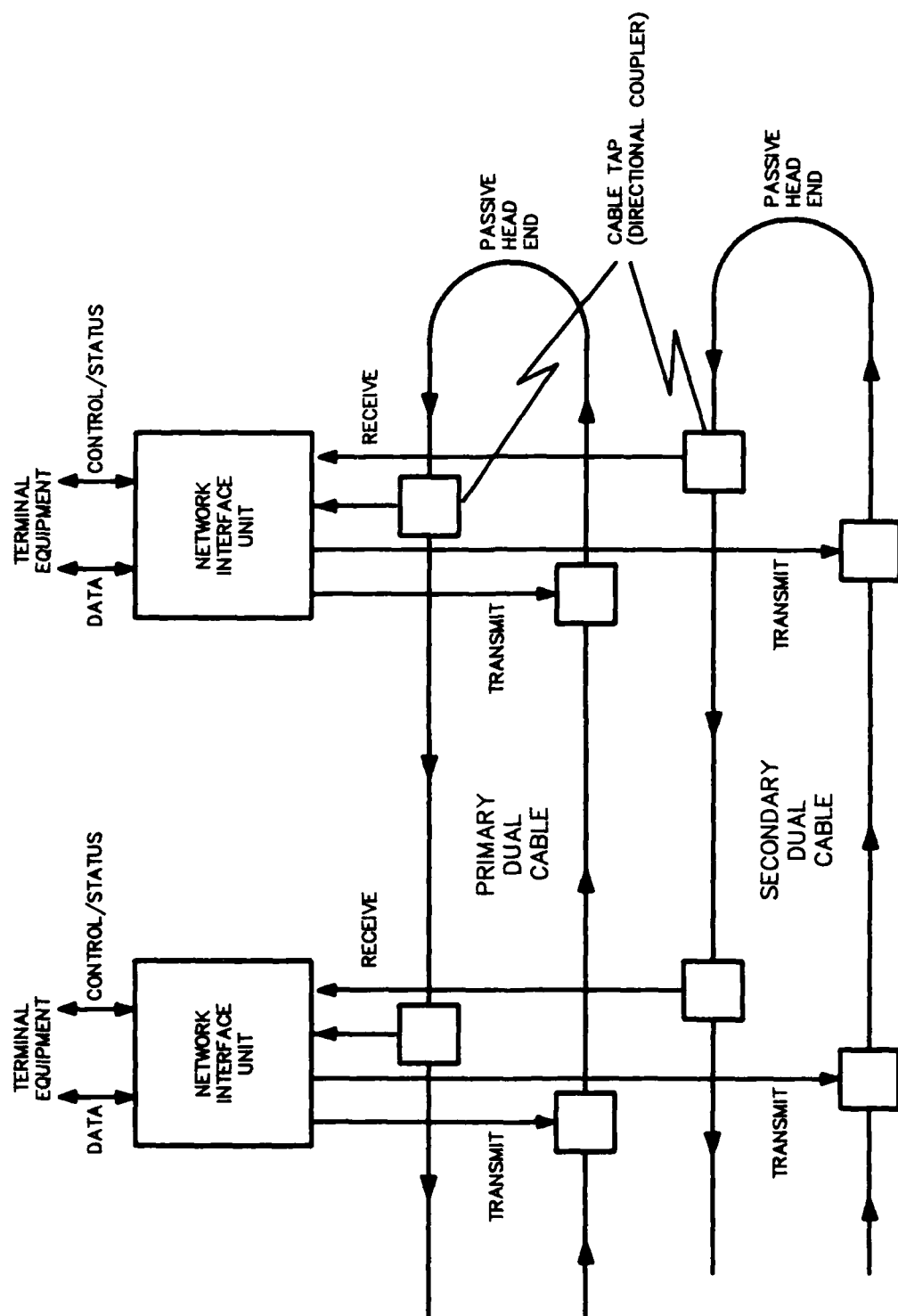


FIGURE 5-1: REPRESENTATIVE BROADBAND BUS LOCAL AREA NETWORK

In SCAN, reliability is further enhanced by connecting all stations to a secondary dual cable system physically separated from the primary system for redundancy. In that case, each network interface unit's transceiver is coupled to the two cables, transmitting on both at all times and receiving from one or the other according to switch selection. Switching between primary and secondary cable systems in the event of failure of the primary system may be performed by central command on the basis of degraded performance or automatically by each transceiver on the basis of monitoring a pilot tone on the primary cable. Such redundancy is appropriate to SCAN where the LAN may be subject to battle damage, but may not be necessary in a DSCS earth terminal.

Figure 5-2 indicates, as an example, the functional capabilities of a broadband bus full intercommunications LAN. The interconnection of terminal equipment via channels of the broadband bus is illustrated, assuming that circuit service channels are provided for the connections between devices and that packet service channels are used for the control and status signals and for management of the local area network itself. Various aspects of this design concept are discussed in the following subsections.

Network Interface Units

Each piece of DSCS terminal equipment attaches to the local area network through a network interface unit (NIU). Generically, the network interface unit in a LAN provides the lowest two levels of the OSI Reference Architecture, the Data Link Layer and the Physical Layer. Such an NIU presents a standardized interface to the local area network, providing a transceiver/modem and the processing power needed to access the LAN and maintain communications quality (i.e., implement the link management functions). To the attached equipment, the NIU presents a compatible interface, and, if necessary, provides any packetization, buffering, addressing, and data handling required for intercommunication via the local area network. Higher levels of the OSI architecture are the responsibility of the communicating devices---it is not the role of a local area network or a network interface unit to insure compatibility between communicating devices.

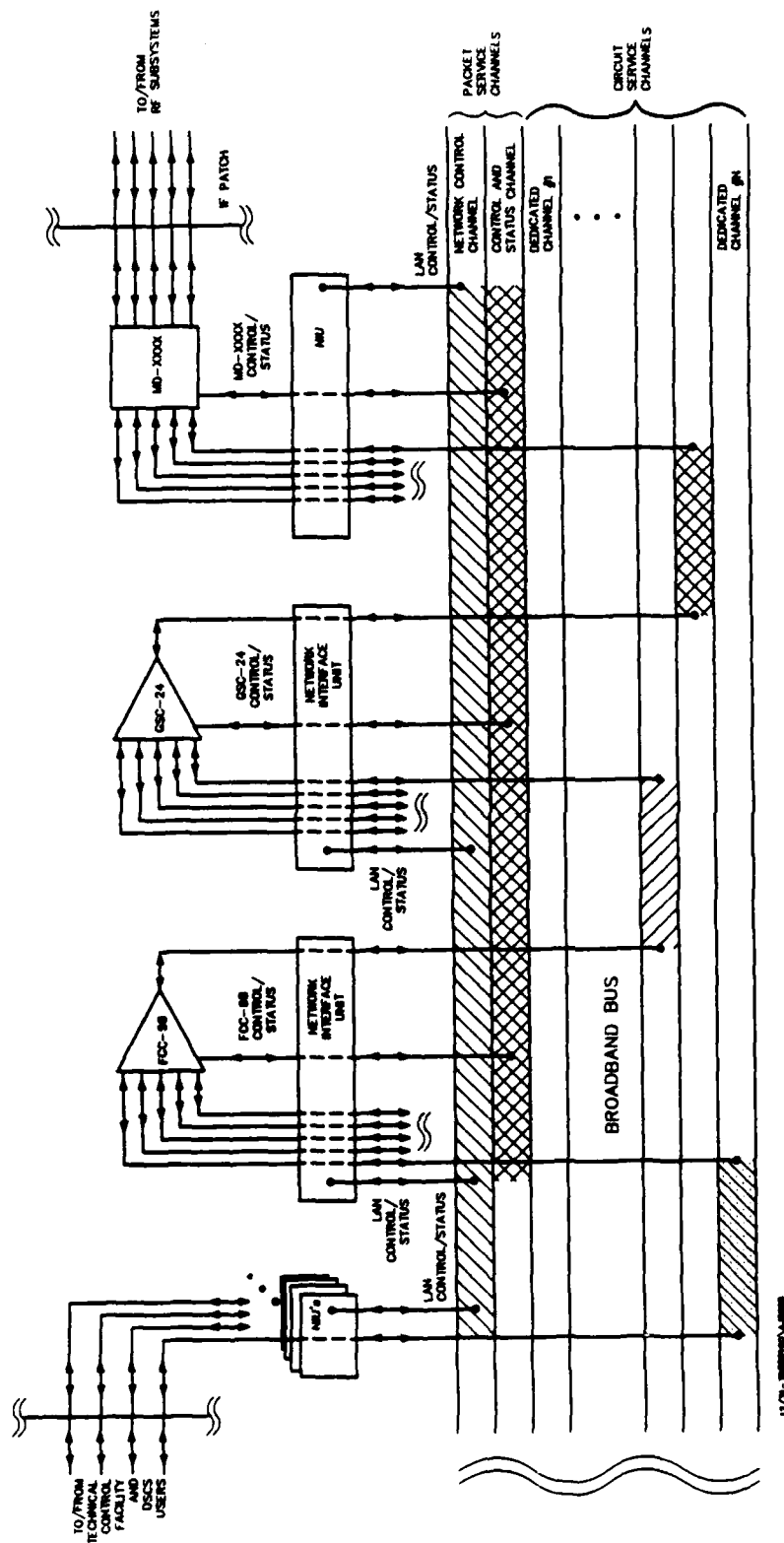


FIGURE 5-2: REPRESENTATIVE USE OF FULL INTERCOMMUNICATIONS LAN

In the case of the full terminal intercommunications broadband LAN envisioned here, the network interface unit may be broken into several distinct functional modules. Such a design would aid in the implementation and deployment of the network interface units and also facilitate maintenance. The network interface units for a particular device would then be made up of the appropriate cable driver, cable receiver, packet service, and input/output modules, as shown in Figure 5-3.

Cable Driver and Cable Receiver Modules. To support the LAN's dedicated circuit-switched channels, two distinct modules, a cable driver and cable receiver module, are indicated. Each must be available in forms capable of supporting either analog or digital signals as is appropriate for the attached device. The cable driver module provides the transmitter and, in the case of digital communications, modulator needed to maintain a dedicated frequency channel on the broadband cable; the cable receiver module provides the receiver/demodulator needed to receive such channels. Unlike the cable driver module, however, the cable receiver module is frequency agile, able to switch among the frequency division multiplexed channels. Equipment configuration control is thus realized by switching channels to that on which the desired device is transmitting.

Cable driver and receiver modules must be available in both analog and digital forms; additionally, the data rates/bandwidths of these modules must suit the attached equipment---again, different versions of these modules would probably be the most cost-effective design. The driver and receiver modules interface via the input/output module to the input and output ports of terminal equipment, thereby providing the transparent equipment intercommunications capability required by DSCS users of the terminal facility. Interfaces are also provided to the NIU's packet service module to permit communication of the local area network's own control and status signals.

Packet Service Modules. Communications on the shared packet-switched channel(s) are controlled and implemented by the NIU's packet service module. Rather than employ dedicated multiple channels for the exchange of equipment and LAN control and status information, a shared packet-switched

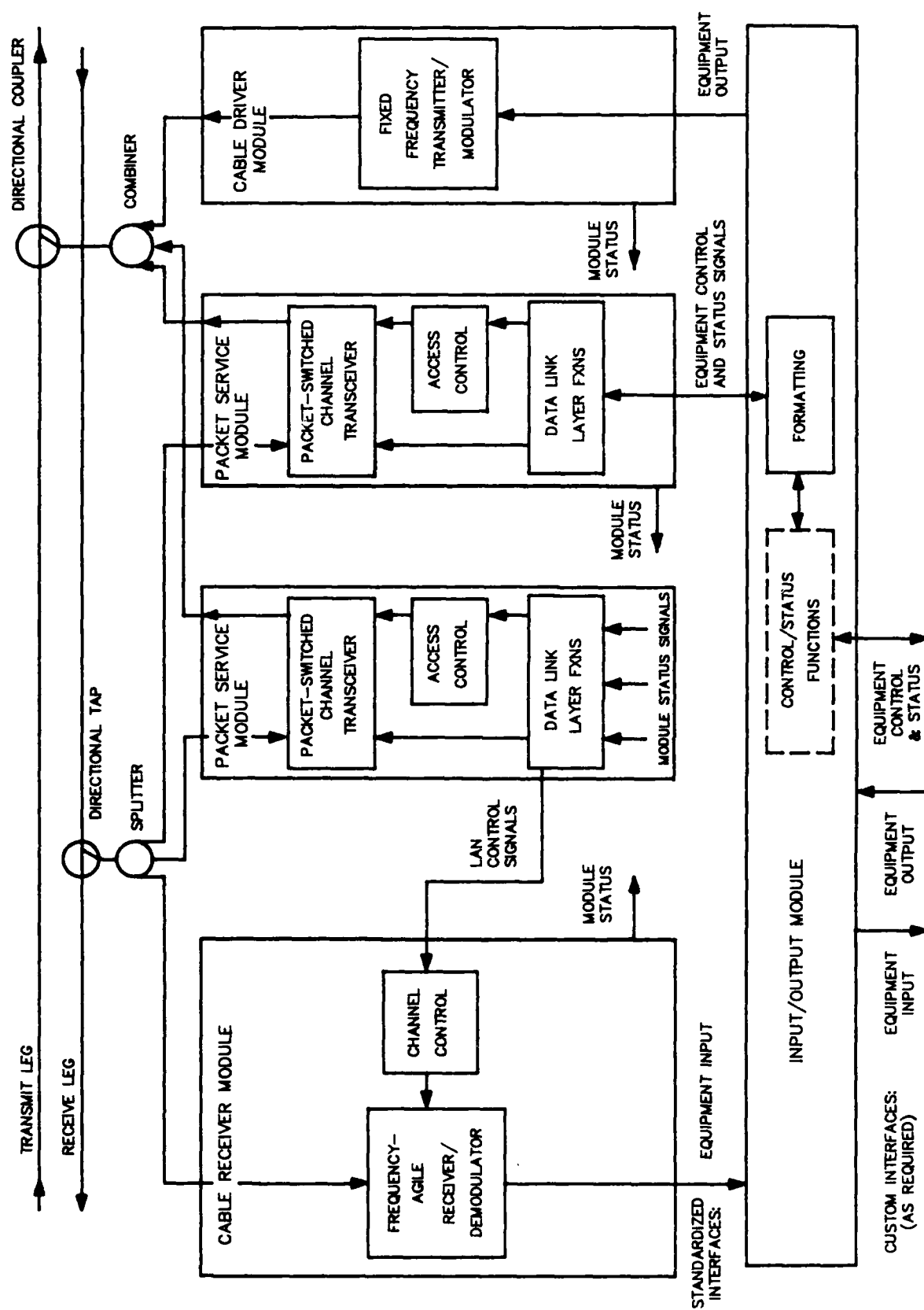


FIGURE 5-3: NETWORK INTERFACE UNIT

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channel makes more efficient use of the LAN's capacity. Either one or more such channels are possible on the broadband bus, allowing further design flexibility. The example of Figure 5-2 shows two such channels, one for LAN management signals and the other for equipment control and status signals; Figure 5-3 accordingly indicates two packet service modules composing a network interface unit in order to establish the two packet service channels.

Access to the packet service channels may be controlled by any of the various possible means available, but SCAN, for example, uses distributed access control in the form of CSMA/CD. Alternatively, it may be desirable to use a centralized access control mechanism standardized for all of the local area network's packet service modules. The choice of access control technique may be based on the control and status signal flows; the broadband bus concept, however, provides the flexibility to design any such scheme with the packet service module providing the necessary processing power.

The packet service module used for LAN management interacts directly with the other modules of the NIU, formatting status information from the modules for communication to the LAN management subsystem and, conversely, responding to packets sent from the LAN controller. Commands interpreted by the LAN management packet service module are relayed to the NIU's cable receiver module to control selection of the received circuit-switched channel and thereby establish the equipment connectivity and terminal configuration. Central monitoring of the local area network may also lead to a command for all stations to switch to a redundant secondary cable; again, the packet service module must respond to such local area network control commands and interface with the other NIU modules appropriately.

Input/Output Modules. Since existing DSCS terminal equipment has typically been designed for interconnection through conventional patch panels, the input/output module provides the necessary interfaces between the attached device and the other modules of the NIU. The equipment input/output ports may require conversion from one electrical and physical interface standard to another while the equipment control and status signals may require

POSSIBLE NETWORK INTERFACE UNIT MODULES

- CABLE DRIVER MODULE
 - FIXED FREQUENCY TRANSMISSION
 - PROVIDES DEDICATED BROADBAND CHANNEL

- CABLE RECEIVER MODULE
 - FREQUENCY AGILE
 - PROVIDES EQUIPMENT CONFIGURATION CONTROL (SWITCHING)

- PACKET SERVICE MODULE
 - SUPPORTS SHARED CHANNEL PACKET SWITCHING
 - IMPLEMENTS MEDIA ACCESS AND DATA LINK LEVEL PROTOCOLS
 - SUPPORTS NETWORK CONTROL RESPONSIBILITIES

- INPUT/OUTPUT MODULE
 - IMPLEMENTS INTERFACES BETWEEN DSCS TERMINAL EQUIPMENT AND OTHER MODULES

special handling to permit their communication via packet-switching. In some cases, the I/O module must possess the processing capability to format and address (packetize) control and status signals sent from a particular equipment and, conversely, to de-packetize received data. For those devices not currently permitting remote control and status interfacing, the I/O module's capabilities might be extended to allow the emulation of the device front panel functions. The I/O module thus presents an appropriate interface to both the attached equipment and the other NIU modules and, in the case of control and status signals, mediates between the data format required by the local area network and that required by the device. Given the possible wide range of I/O module responsibilities and the need to accommodate all the ports of the attached device, the I/O module itself might be constructed in modular form.

As an example of the types of physical interfaces that must be supported by the NIU I/O modules, Table 5-2 documents the interfaces supported by SCAN for the packet and circuit service channels. The indicated wide range of interfaces is not handled by any single module, but rather by different versions of SCAN's I/O and cable driver/receiver modules. Due to the disparate nature of the current DSCS terminal equipment, the network interface units of any local area network introduced into the terminal will be required to support a similar variety of interfaces.

Modular Construction of the NIU. The connection of a device to the full intercommunications LAN thus involves the selection and assembly of the appropriate NIU modules: the I/O module(s) accommodating the equipment's particular input, output, and control and status ports must be chosen as must either digital or analog versions of the cable driver and receiver modules. A cable driver module is needed for each output of any single piece of equipment; a cable receiver module is needed for each equipment input. The design of the modules might possibly be based on a shared power and interface bus so that PC-cards corresponding to each module may readily be replaced and interchanged in a standard NIU chassis. Ideally, the functions of the NIU would be incorporated into the design of future DSCS terminal equipment, but as of now it is unlikely that the NIU modules may even draw power from the attached device.

TABLE 5-2

SCAN EQUIPMENT INTERFACES
PACKET SERVICE INTERFACES (I/O MODULES)

MIL-STD-1397A	PARALLEL, 41667 WPS
MIL-STD-1397A/B/C	PARALLEL, 250 KWPS
MIL-STD-1397D/E	SERIAL, 10 MBPS
MIL-STD-1553B*	SERIAL, 1 MBPS
IEEE 488 (GPIB)*	PARALLEL, 1 MWPS

MIL-STD-188-114/100 ELECTRICAL CHARACTERISTICS

RS-232C	75, 150, 300, 600, 1200, 2400, 4800, 9600, 19200 BPS
RS-422A	75, 150, 300, 600, 1200, 2400, 4800, 9600, 56000 BPS
RS-423A	75, 150, 300, 600, 1200, 2400, 4800, 9600, 56000 BPS
RS-449	75, 150, 300, 600, 1200, 2400, 4800, 9600, 19200, 56000, 112000, 224000 BPS
20 mA CURRENT LOOP	50, 75, 150 BAUD/SEC

CIRCUIT SERVICE INTERFACES (CABLE DRIVER/RECEIVER MODULES)

MIL-STD-1397A/B/C/D/E
 MIL-STD-1553B*
 RS-232C
 RS-422A
 RS-423A
 MIL-STD-188-100 ANALOG

* NIU PROVIDES BUS CONTROL OF POLLED BUS INTERFACE.

Final installation of a device is accomplished once the transmit frequencies of the NIU's cable driver modules (assuming more than one device output) are logged with the LAN controller and the NIU's cable receiver modules and those of other NIU's are commanded to establish the desired connectivity.

LAN Management

The control of the full intercommunications LAN is the responsibility of the LAN management subsystem. Under operator control, such a controller should provide rapid display of the local area network status, exhibit the existing connectivities, and allow control of all LAN functions. A database of the equipment connections, associated NIU capabilities, and circuit service channel assignments must be maintained and the means to transmit control packets instructing the cable receiver modules to switch frequencies must be supported. Ideally, the subsystem would provide a user-friendly interface, allowing easy understanding of the equipment configurations implied by the channel assignments and providing assistance in establishing new configurations, especially to warn the operator of improper or inappropriate connections.

Classified/Unclassified Data

Earth terminal intercommunications, either at a Network Control Terminal or Network Terminal, involves the handling of classified data. At a Network Control Terminal, the signal quality data for a particular link is not classified, but the aggregate of such data for many Network Terminals is considered classified. At Network Terminals, DSCS network configuration data is classified while equipment status and control information is unclassified. DSCS user communications are not classified since it is assumed that the users themselves are responsible for the encryption of any secure communications; configuration definition data received over the Critical Control Circuits, however, is classified.

Relay of classified (red) data must be within a designated red area of the terminal and, except for terminals within the DSCS Operations Center, must be supported by devices which are TEMPEST qualified. If classified data is to be supported by a local area network, that LAN must fulfill such requirements. Neither TDMA or FDMA reservation schemes supported on a bus topology can satisfy these communications security requirements, indicating that a second, independent full intercommunications LAN is needed to support red data. This LAN would not have to support the same aggregate throughput as the black full intercommunications LAN, but it should support the intra-terminal relay of decrypted Critical Control Circuits. In order to prevent classified data from entering a black area, the intercommunication of data between red and black LAN's must be protected by Line Guardian Units and/or encryptors/decryptors.

LAN Access and Terminal Configurations

If the full intercommunications LAN concept is to be applied, two distinct LAN access approaches are possible. User signals interface to the DSCS network through the Technical Control Facility which provides the necessary interface equipment. The DSCS user signals are then typically presented to the Digital Communications Subsystem (DCSS) through the Main Distribution Frame. Either these signals may be each connected to NIU's and directed to the appropriate DCSS equipment through the broadband LAN (as shown in the example of Figure 5-2) or they may be routed by cable directly to the first stage of DCSS equipment which, in turn, is connected to other DCSS equipment via the local area network. The two approaches have their advantages and disadvantages; either alternative may be pursued without significantly affecting the design concept, although the choice does somewhat alter the way in which the local area network accommodates a particular terminal configuration.

Direct User Access. The first technique, direct user access to the intercommunications LAN, involves many NIU's and may require special consideration of non-standard equipment interfaces to Technical Control

Facility devices. Since user channels are typically multiplexed in the DCSS, the number of user channels is greater than the number of equipment-to-equipment channels and hence the need for many more NIU's and broadband LAN channels. If user channels are given channels on the LAN, however, the wide range of data rates may lead to a complicated, expensive NIU design in addition to requiring many more of them.

Equipment-to-Equipment Interconnections Only. If the LAN only supports equipment-to-equipment interconnections within the DCSS, on the other hand, the ability to control equipment configurations and the flow of user signals through the terminal would be limited to just those interconnections supported by the LAN---the connections between user circuits in the Technical Control Facility and the first stage of DCSS equipment would not be controllable by the LAN. The problem of interfacing to the local area network, however, becomes simplified. Existing earth terminal devices or, ideally, some other equipment providing a remote configuration control capability would be used as the user interface. In this regard, the possibility of a hybrid LAN/IMPAT design might be considered.

Hybrid LAN/IMPAT. The Integrated Multiplex, Patch, and Test (IMPAT) equipment discussed at length in Section 6 of this report might be employed as a user circuit interface to a full intercommunications LAN. User circuits would still be supported via a local area network, but the task of user circuit access to the LAN would be simplified by using the IMPAT. The IMPAT provides an electronic patch capability, able to dynamically switch input and output connections, and also performs a variety of multiplexer functions, including the emulation of existing DCSS multiplexers. User circuits might thus connect to IMPAT devices as the first stage of DCSS equipment and then, after any appropriate multiplexing, be interfaced (via NIU's) to the full intercommunications LAN. The advantage realized through using the IMPAT in this way is, first, the reduction in the number of NIU's required to interface to the LAN, and, second, the ability to control user circuit connections to the first stage of DCSS equipment through the IMPAT's electronic patch capability.

DSCS Terminal Configurations. Four different DSCS terminal configurations are possible, as discussed in Section 3 and shown in Figure 5-4. The differences among these configurations must be addressed by any terminal local area network design. Case III defines the simplest configuration in which the Technical Control Facility and the Earth Terminal are located in the same facility. The full intercommunications LAN may then support user signals either at the interface between the Technical Control Facility and the Digital Communications Subsystem or after the first stage of DCSS processing, as discussed above.

In the other three cases, the Technical Control Facility and Earth Terminal are in separate facilities, transparently linked by the Interconnect Facility (ICF) via coaxial or fiber-optic cable or line-of-sight microwave transmission. Cases II and IV are alike in that elements of the DCSS are present in both facilities; in Case I, the DCSS is only in the Earth Terminal facility. In Case I, then, the full intercommunications LAN need only be provided in the Earth Terminal facility, interfacing to the Earth Terminal's Interconnect Facility. The role of the Interconnect Facility is to collect and distribute terminal signals in support of their intercommunication between the two separate terminal facilities; in Case I, the signals at the ICF are effectively the DSCS user signals.

In Cases II and IV, however, the full intercommunications LAN should support intercommunications in both facilities. Use of point-to-point links to connect cable segments in a local area network is not at all exceptional. Typically, the only constraint on such links is due to the possible effects of propagation delay on the effective operation of the LAN's access control protocol. In the full intercommunications LAN discussed here, only the packet-switched channels would be subject to such limitations, and even then the access control technique may be designed to account for the worst-case end-to-end propagation delays envisioned. The point-to-point link between facilities may take advantage of the full intercommunication LAN's frequency division multiplexing or the

multiplexing scheme of an existing Interconnect Facility may be used. The latter possibility is not particularly attractive since it requires the multiplexing/demultiplexing of the entire broadband bus, but it is possible: the Interconnect Facility would be effectively treated as a single device supported by the full intercommunications LAN with connections to all other devices.

Reliability and Cost

While the discussion of the full intercommunications LAN has thus far concerned the satisfaction of functionality and flexibility requirements, the representative design concept of a broadband LAN allows some initial comments to be made concerning reliability and cost.

Reliability. The reliability of any local area network may be assessed from two points of view: the reliability of the hardware/software (i.e., the network interface unit) used to connect a particular device to the local area network and the reliability of the LAN as a whole in maintaining its functionality in the event of the failure of a particular attached device and/or its network interface unit. These two points of view are most distinct in decentralized systems where the network interface units are fairly complex in order to control the working of the LAN in a distributed fashion. Depending on the exact system implementation, the network interface units may be somewhat less complex in a centralized LAN, but performance is dependent on fault-free operation of the central LAN controller. In any design of a full intercommunications LAN, distributed control is a desirable attribute to enhance reliability.

In the local area network proposed here as representative of a full intercommunications LAN, control is distributed: network interface units provide the transceiving and processing capabilities needed to access the broadband cable plant and control LAN operation. There is centralized control in the sense that the LAN management subsystem co-ordinates connectivity through the assignment of channels, but it is the individual

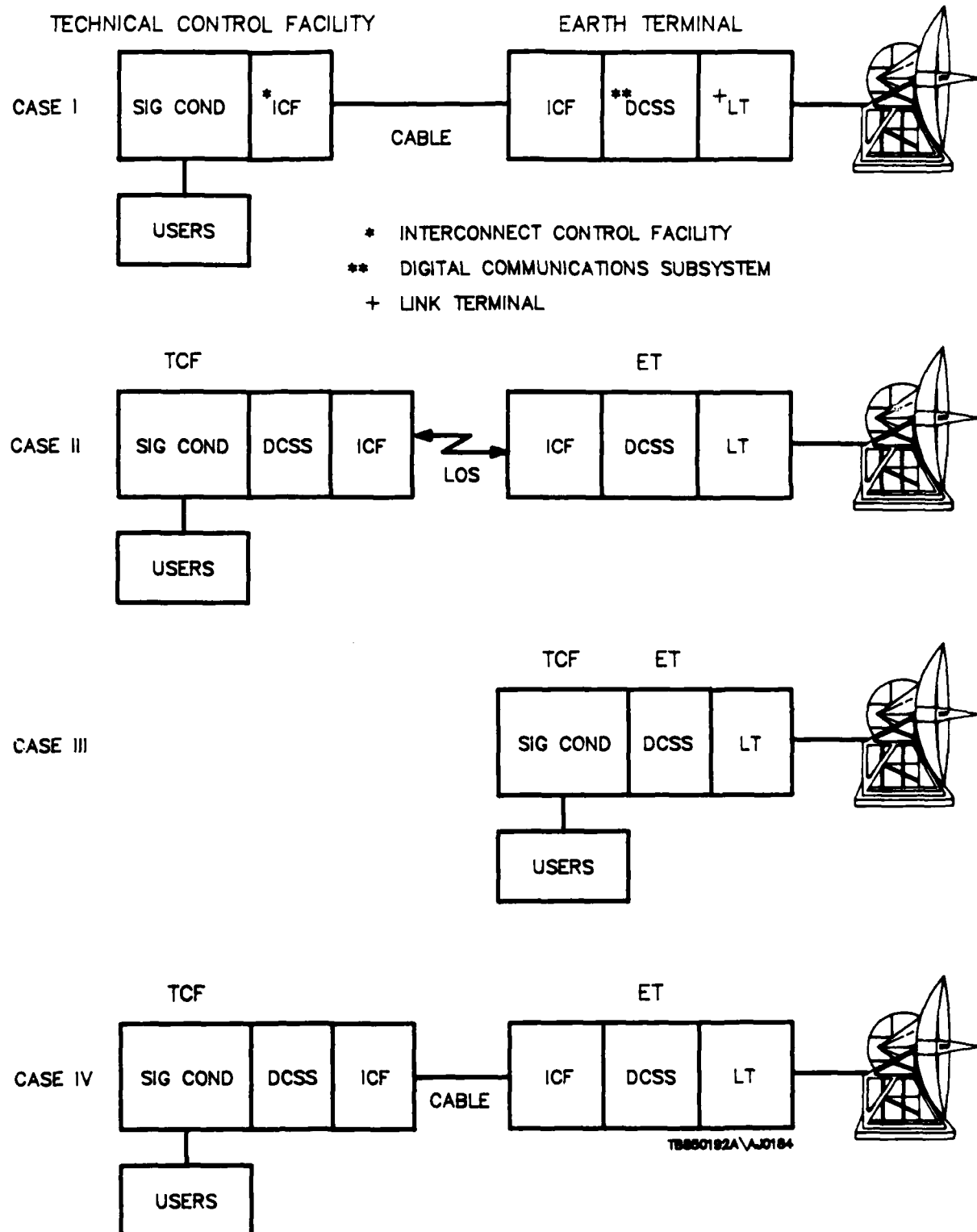


FIGURE 5-4: EARTH STATION CONFIGURATIONS

NIU's which, in response to such commands, actually effect the working of the local area network. Depending on the actual design, the LAN, once configured, could maintain performance even in the event of failure of the LAN management subsystem. The ability to control equipment configurations, of course, would be lost while repairs are made or a backup management subsystem brought on-line.

The support of full DSCS terminal intercommunications by a local area network is necessarily more complicated than simply using patch cords and a manual patch panel---the network interface units required for each attached piece of equipment represent fairly sophisticated devices in themselves. Failure of an NIU is thus a very real possibility, although hopefully the NIU design would disallow failures which cause the NIU to jam and disrupt the local area network. Failure of an NIU is effectively the same as the failure of its associated equipment---the user circuit supported by the affected equipment chain is broken. Once the source of the failure is identified, however, redundant equipment may be switched on-line as long as the local area network itself is still operational. The full intercommunications LAN design concept presented here reflects the desire for LAN reliability: a coaxial bus readily tolerates the failure of attached devices without affecting the other working components. Other designs, of course, may be similarly capable of providing fail-safe local area network operation.

Cost. No precise estimate of the cost of a full intercommunications LAN for the DSCS earth terminals is possible at this stage---only issues and concepts have been presented, not a complete design. Nonetheless, some conjectures may be advanced. While the costs of the LAN transmission media and the local area network's installation are non-trivial items, the major costs are involved in the network interface units required to link each terminal device to the local area network. Costs of the NIU's may be categorized as either development or unit costs. Development costs will be incurred if the full intercommunications LAN design cannot be fulfilled using existing equipment and components but instead requires the design and development of new devices; unit costs are here interpreted as the production costs of each NIU after the development phase.

Development costs reflect the effort involved in designing the software/hardware needed to implement the envisioned network interface units. In the case of the full intercommunications LAN discussed here, no product is presently commercially available which provides the needed connectivities and data rates. The technology to implement a full intercommunications LAN is not out of reach of current capabilities---it is merely a question of applying existing and well-known technology to the specific task. The I/O modules will especially require attention since they must perform the interface conversion between the various terminal devices and the local area network. And further design efforts are necessary if the I/O modules are to provide remote control and status monitoring features for devices which do not themselves provide such capabilities. As a very rough estimate, the development cost for each of the four modules may be between \$100,000 and \$500,000. Development costs, although ostensibly high, may be distributed over the number of devices produced, thereby somewhat limiting the cost impact. Furthermore, development costs may be significantly defrayed if an effort is made to use as much commercially available equipment as possible; this approach has been followed in the implementation of the Modular Building-Block Data Bus in order to speed delivery.

Unit costs reflect the manufacturing expenses involved in producing the NIU's. The cost of commercial NIU's range from approximately \$200 (for circuit board implementations) to tens of thousands of dollars for more complex stand-alone units. Although the NIU modules described as representative of those needed in a full intercommunications LAN do not have identical capabilities, assume, as a first approximation, that the NIU modules each cost \$1500, with the cost of the NIU chassis distributed over the four different modules. This figure is consistent with the estimated costs of elements of the Modular Building-Block Data Bus; according to conversations with Col. Fred Albertson, that system's Bus Interface Unit used for handling digital data, for example, is estimated at \$2000, while the off-the-shelf 10 Mbps COMTEC frequency-agile modem used in the system costs approximately \$1400-1500.

In the example full intercommunications LAN considered here, a cable driver module is required for every equipment output, a cable receiver module is required for every input, and for each device one I/O module and two packet service modules are assumed, in keeping with the illustration of Figure 5-3. Other NIU configurations are of course possible: more than one I/O module might be required per device if they are each designed for a limited number of ports; one or two packet service modules may be used depending on the number of packet service channels on the LAN; the cable driver and receiver modules might be designed to support multiple channels, thereby reducing the number of modules required; and/or the NIU design might, while retaining modularity, share processing or transceiving capabilities among modules. For the purposes of this discussion, however, the initially stated assumptions apply.

Table C-4 of Appendix C lists the maximum number of input and output ports for various terminal devices and provides estimates of the number of devices (both active and redundant) employed in the baseline light, medium, and heavy terminals. Employing the data of Table C-4, Table 5-3 then provides an estimate of the number of NIU modules required for the various equipment types and for the user circuits specified in Table 3-1. Since the maximum number of I/O ports is assumed, the estimated number of modules is somewhat inflated, but, nonetheless, the subtotals and totals indicated in Table 3-1 provide some measure of the full intercommunications LAN requirements. The subtotals refer to the number of modules needed if user circuits are patched to the first stage of multiplexing: with approximately 374, 1609, and 2442 modules needed for light, medium, and heavy terminals, respectively, the corresponding NIU expense per terminal is approximately \$561,000, \$2,413,500, and \$3,663,000, depending on the terminal size. If user circuits are introduced directly to the LAN, then an additional number of NIU's are required. It is assumed that the NIU's used for this purpose will not require an I/O module or a packet switch module for equipment control and status signalling, but will merely use a cable driver and cable receiver module and a packet service module to control the

TABLE 5-3
ESTIMATED NUMBER OF NIU MODULES

EQUIPMENT TYPE	MODULE TYPE	NUMBER REQUIRED PER TERMINAL TYPE		
		LIGHT	MEDIUM	HEAVY
ECCM R/T UNITS	CABLE DRIVER	4	14	31
	CABLE RECEIVER	4	14	31
	I/O	4	14	31
	PACKET SERVICE	8	28	62
MD-1002 R/T UNITS	CABLE DRIVER	4	9	33
	CABLE RECEIVER	4	9	33
	I/O	4	9	33
	PACKET SERVICE	8	18	66
KY-883	CABLE DRIVER	10	48	134
	CABLE RECEIVER	10	48	134
	I/O	5	24	67
	PACKET SERVICE	10	48	134
LRM	CABLE DRIVER	39	143	52
	CABLE RECEIVER	39	143	52
	I/O	3	11	4
	PACKET SERVICE	6	22	8
GSC-24	CABLE DRIVER	50	175	325
	CABLE RECEIVER	50	175	325
	I/O	2	7	13
	PACKET SERVICE	4	14	26
FCC-98	CABLE DRIVER	50	300	400
	CABLE RECEIVER	50	300	400
	I/O	2	12	16
	PACKET SERVICE	4	24	32
<u>SUBTOTALS</u>	CABLE DRIVER	157	689	975
	CABLE RECEIVER	157	689	975
	I/O	20	77	164
	PACKET SERVICE	40	154	328
	SUBTOTAL	374	1,609	2,442
USER CIRCUITS (SEE TABLE 3-1)	CABLE DRIVER	118	562	762
	CABLE RECEIVER	118	562	762
	I/O	-	-	-
	PACKET SERVICE	118	562	762
<u>TOTALS</u>	CABLE DRIVER	275	1,251	1,737
	CABLE RECEIVER	275	1,251	1,737
	I/O	20	77	164
	PACKET SERVICE	158	716	1,090
	TOTAL	728	3,295	4,728

NIU itself. The number of modules required is then significantly greater: approximately 728, 3295, and 4728 modules are needed for light, medium, and heavy terminals, respectively, indicating a corresponding NIU expense of \$1,092,000, \$4,942,500, and \$7,092,000.

Observations

The full DSCS terminal intercommunications LAN concept presented here attempts to reconcile the conflicting needs of DSCS dedicated user circuits with LAN technology. Local area networks are typically constructed to support peer-to-peer or master-slave data communications---the dedicated "through" communications characteristic of a DSCS earth terminal are not normally addressed by LAN technology and approaches. Nonetheless, the Navy's SCAN provides a precedent in supporting such dedicated circuit-switched communications with a local area network and serves as an example in demonstrating the capabilities required to support full terminal intercommunications.

In the Navy's intended application, however, the physical dispersal of communications equipment on-board ship justifies the introduction of LAN technology. For the DSCS earth terminals, often all equipment is in one shelter. The network interface units required to support the connection of terminal equipment to the full intercommunications LAN may involve a single board added to the equipment or, more likely, may require a full rack shelf. The introduction of such network interface units may thus possibly demand an inordinate amount of scarce rack and shelter space in comparison to the space conserved by the replacement of the current manual patch panels. And the network interface units themselves represent a fairly complex technology compared to the use of patch panels---the estimated NIU costs per terminal represent a considerable investment.

On the other hand, use of a full terminal intercommunications LAN would simplify the installation of a terminal and eliminate most if not all of the distribution frames and patch panels currently employed. The LAN is

consistent with the desire for remote control and access capabilities and, as discussed in the next section, can actively support a wide range of control concepts. Possibly the most significant feature, however, is provided by the capabilities implicit in use of the LAN for terminal configuration control. A LAN management subsystem was speculated in a previous subsection as a means of controlling the LAN connectivities and hence the terminal configuration---a user-friendly such system would speed the error-free set-up of terminal configurations and reduce the demands made upon terminal personnel. The potential savings in time and, perhaps, staffing might offset the development and deployment costs.

The design of a full intercommunications LAN for DSCS earth terminals is thus feasible, but may not provide a cost-effective approach to terminal subsystem integration.

5.3 CONTROL AND STATUS LAN

Introduction

A control and status LAN for the DSCS earth terminals must support the intercommunication of control and status signals between DSCS terminal equipment and subsystems and the terminal's control and status monitor processor(s). A control and status LAN is not intended to support the relay of user signals through the terminal---that interconnect function is assumed to be performed by some other means. The number and variety of signals to be handled by the control and status LAN is thus quite less than in a full intercommunications LAN. The communication of control and status signals between devices---because dedicated channels are not required and low data rates are involved---closely corresponds to the type of communications typically served by local area networks. Consequently, commercial, off-the-shelf local area network technology may be suitable. The desired connectivity and communications flows must be known, however, in order to determine the most appropriate local area network design.

Some of the existing DSCS subsystems---for example, the DSCS ECCM Control Subsystem (DECS) and the DSCS FDM Control Subsystem (DFCS)---involve a processor which communicates with the subsystem's associated equipment directly. The communications are established via interfaces such as RS-449, RS-232-C, or the IEEE 488 bus. Unfortunately, current DSCS devices do not adhere to any one, single interface standard. If these devices are to be directly connected to a control and status LAN, a network interface unit for each device would be required to perform the necessary physical and data link layer interfacing. Future DSCS equipment, however, might include standardized control and status LAN interfaces, incorporating the functions of a network interface unit into the device.

The development of a control and status LAN for the DSCS earth terminals can be seen as part of an overall effort to integrate the various terminal subsystems and equipment. The preliminary MIST design, for example,

CONTROL AND STATUS LAN: INTRODUCTION

- SUPPORTS INTERCOMMUNICATION OF CONTROL AND STATUS SIGNALS BETWEEN DSCS TERMINAL EQUIPMENT AND CONTROL/STATUS MONITOR PROCESSOR(S)
- DOES NOT SUPPORT INTERCONNECTION OF DEVICES FOR RELAY OF USER COMMUNICATIONS THROUGH TERMINAL
- SOME EXISTING SUBSYSTEMS (E.G., DECS, DFCS) PROVIDE SELF-CONTAINED CONTROL/STATUS COMMUNICATION CAPABILITIES
 - TYPICAL EQUIPMENT INTERFACES:
 - DECS/LRM: RS-449
 - DECS/USC-28: RS-232-C
 - MX-9922/DFCS: IEEE 488
- FUTURE USE OF CENTRAL PROCESSOR IN MIST AS
 - CONTROLLER
 - STATUS MONITOR
- FUTURE SUBSYSTEMS MAY PROVIDE STANDARDIZED C&S LAN INTERFACES

specifies a central processor to be used as controller and status monitor of the terminal equipment. The design of a control and status LAN to support such a concept will depend on the planned role of such a central controller/monitor. Two fundamental connectivity strategies for the control and status LAN are seen as likely candidates, each approach making different assumptions as to the nature of the control and status monitoring system. Neither of the two approaches, however, leads to a specific LAN design. Unlike the situation in considering the local area network support of full terminal intercommunications, no one issue narrows the number of possible alternatives---the communications problem admits many of the solutions provided by the various local area network options. As a consequence, the ultimate choice of local area network technology need not be custom- designed, but may take advantage of existing products.

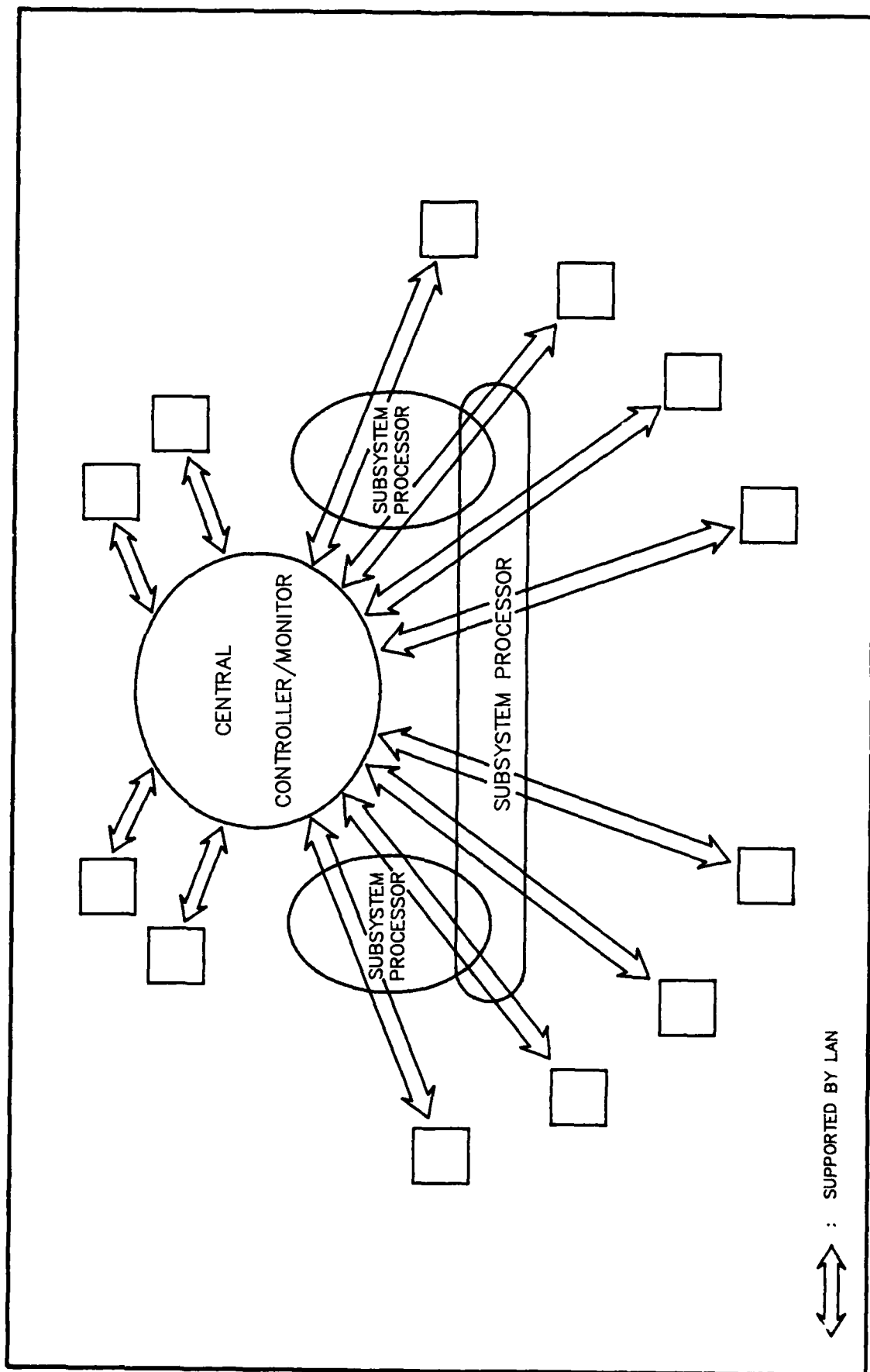
Connectivity Strategies

The control and status monitor functions and, more importantly, the distribution of those functions, will determine how best to design the control and status local area network. Two LAN connectivity strategies are apparent, each reflecting different philosophies in the terminal control and status monitor capabilities.

Connection of All Terminal Equipment. One concept of the control and status LAN assumes that all terminal equipment will be directly connected to the local area network, as in the full intercommunications LAN. The relay of equipment control and status signals will be supported by the LAN, replacing the existing intra-subsystem connections between subsystem processors and supported equipment. Communications between the various terminal devices and the subsystem processors and any central control/monitor processor will be through the LAN. Figure 5-5 illustrates in an abstract fashion how each device communicates to the central processor and, if appropriate, to its subsystem processor. The figure is not meant to suggest that a star topology is the only possible LAN configuration, but merely illustrates the communication flows and functional responsibilities.

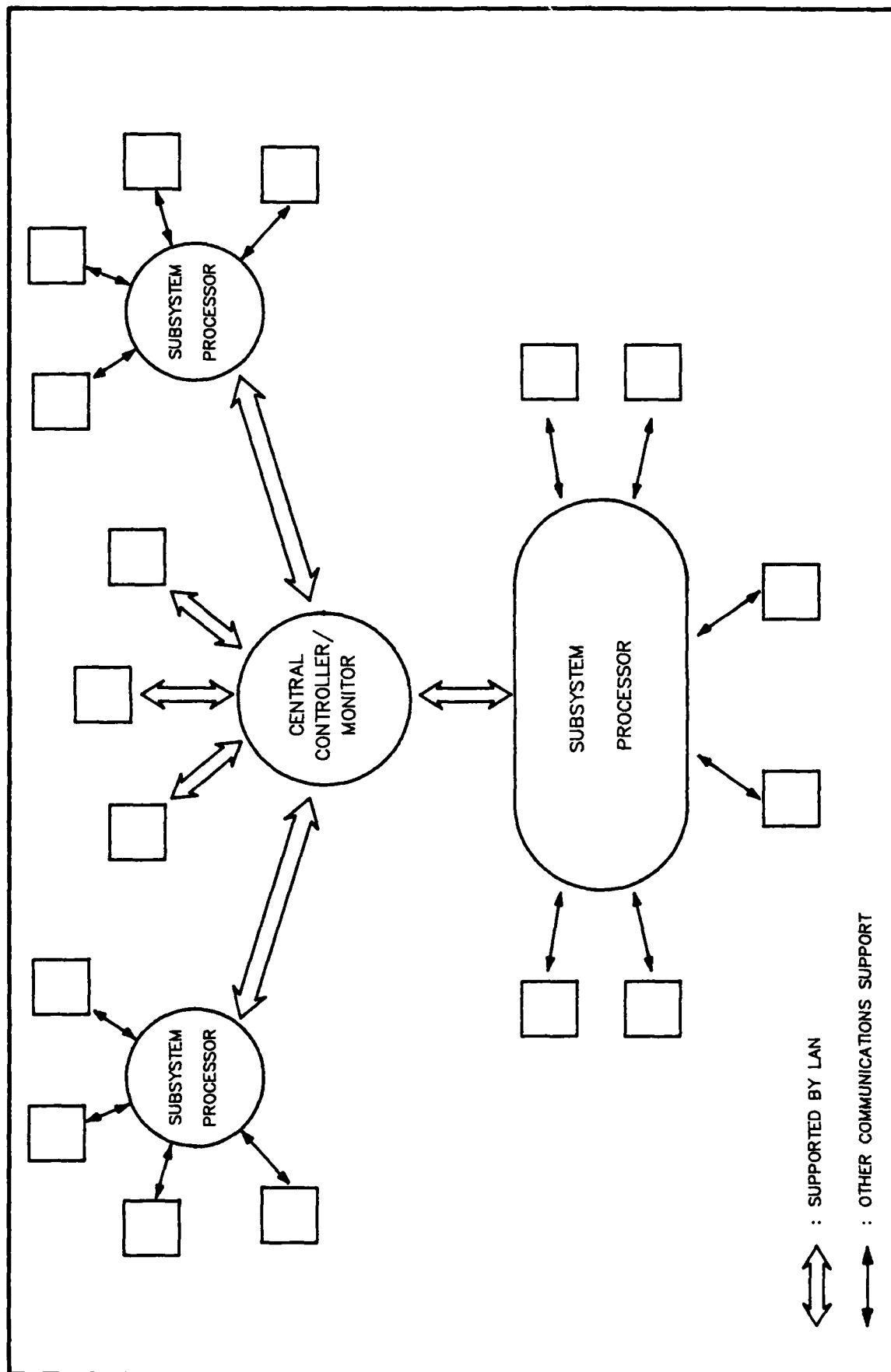
CONTROL AND STATUS LAN: CONNECTIVITY STRATEGIES

- LAN DESIGN REFLECTS ROLE OF CENTRAL CONTROLLER/MONITOR
- INTERCOMMUNICATION OF CONTROL AND STATUS DATA FROM ALL TERMINAL EQUIPMENT (E.G., FULL INTERCOMMUNICATIONS LAN)
 - EQUIPMENT C/S SIGNALS COMMUNICATED TO/FROM CENTRAL PROCESSOR AND/OR SUBSYSTEM PROCESSOR(S) VIA LAN
 - LAN REPLACES EXISTING INTRA-SUBSYSTEM CONNECTIONS
 - THIS APPROACH SUPPORTS POSSIBLE ASSUMPTION OF ALL SUBSYSTEM CONTROL/MONITOR RESPONSIBILITIES BY CENTRAL PROCESSOR, ELIMINATING SUBSYSTEM PROCESSORS
- INTERCOMMUNICATION BETWEEN CENTRAL PROCESSOR AND SUBSYSTEM PROCESSORS ONLY
 - PEER-TO-PEER COMMUNICATIONS BETWEEN PROCESSORS VIA LAN
 - SUBSYSTEM PROCESSOR/EQUIPMENT INTERCONNECTIONS NOT SUPPORTED BY LAN; EXISTING C/S INTERCONNECTIONS MAINTAINED
 - SUBSYSTEM PROCESSORS MAY RETAIN CURRENT ROLES; CENTRAL PROCESSOR USED IN SUPERVISORY MODE AND/OR TO COLLECT/DISTRIBUTE DATA
 - ALTERNATIVELY, SUBSYSTEM PROCESSORS MAY ACT AS INTELLIGENT EQUIPMENT INTERFACES SUBORDINATE TO CENTRAL PROCESSOR



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FIGURE 5-5: INTERCOMMUNICATION OF CONTROL AND STATUS DATA FROM ALL TERMINAL EQUIPMENT
COMMUNICATION FLOWS AND FUNCTIONAL RESPONSIBILITIES



1B860100\AJ0426

FIGURE 5-6: INTERCOMMUNICATION BETWEEN CENTRAL PROCESSOR AND SUBSYSTEM PROCESSORS ONLY

COMMUNICATION FLOWS AND FUNCTIONAL RESPONSIBILITIES

Since the control and status LAN described here supersedes all intra-subsystem connections, such a concept lends itself well to the assumption of all control and monitor responsibilities by the central processor. In that case, the subsystem processors are eliminated, their roles taken over by the central processor. If that is indeed the function of the central processor, then a star topology probably does best serve the communications requirements. Alternatively, if the subsystem processors are retained, then a ring or bus LAN topology might be more suitable in supporting the control and status signal flows.

Connection of Subsystem Processors. The presence of the subsystem processors suggests a second connectivity strategy for the control and status LAN. Since the subsystem processors already interface to their associated equipment, the control and status LAN may be used to support intercommunications between the central processor and subsystem processors only. The resulting peer-to-peer communications between processors is the type of communications addressed by most commercially available LAN's. This control and status LAN concept is represented by the abstraction of Figure 5-6, showing also how some terminal devices may communicate directly to the central controller/monitor if they are not supported by a subsystem processor.

This second approach to the control and status LAN design suggests two extreme roles for the central processor. In one case, the subsystem processors retain their current responsibilities, relaying data back to the central processor which acts a monitor of subsystem activities. At the other extreme, the central processor may assume the responsibilities of the various subsystem processors, using the subsystem processors as intelligent interfaces to the supported devices. Other intermediate roles for the central processor are of course possible, but in all cases the subsystem processors maintain direct interfaces to their associated devices.

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Considerations

The two connectivity strategies presented above, while not leading to a specific LAN design, do imply certain LAN attributes.

In the case of a control and status LAN which connects all terminal equipment, such an approach implies the need for network interface units suitable for all equipment types. While future DSCS equipment may incorporate the needed LAN interfaces, attachment of current equipment would require the development of network interface units. As in the full intercommunications LAN, the network interface units administer the lowest levels of the OSI Reference Architecture. And, as mentioned in the discussion of the control and status capabilities of the full intercommunications LAN, control and status signals may be communicated by dedicated channels (implying a reservation access control protocol) or by the techniques of packet-switching. The choice determines the access control protocol implemented by the network interface units.

By connecting all terminal equipment to the control and status LAN, the number of network interface units required is considerably higher than in the second connectivity strategy. Nonetheless, if the terminal central processor is to assume the responsibilities of current subsystem processors, this design approach represents the most far-sighted step toward subsystem integration.

On the other hand, if the responsibility of interfacing to the individual pieces of terminal equipment rests with the subsystem processors, then the control and status LAN would support intercommunications between processors. The connection of the subsystem processors to the local area network requires a network interface unit, but the processing power of the processors may be used. Indeed, the role of network interface unit may be accomplished through the relatively simple addition of software and/or hardware to the existing processor systems. Separate network interface units would be necessary for those devices not currently supported by a subsystem processor yet requiring communications to the central processor.

CONTROL AND STATUS LAN: CONSIDERATIONS

- INTERCOMMUNICATION OF CONTROL AND STATUS DATA FROM ALL TERMINAL EQUIPMENT
 - REQUIRES NETWORK INTERFACE UNITS SUITABLE FOR ALL EQUIPMENT TYPES
 - DEVELOPMENT AND DEPLOYMENT COSTS
 - RACK SPACE
 - FUTURE SUBSYSTEMS AND EQUIPMENT MAY INCORPORATE NEEDED LAN INTERFACE AND CONTROL/STATUS CAPABILITIES
 - DEPENDING ON CENTRAL PROCESSOR ROLE, THIS MAY BE THE MOST FAR-SIGHTED DESIGN APPROACH
- INTERCOMMUNICATION BETWEEN CENTRAL PROCESSOR AND SUBSYSTEM PROCESSORS ONLY
 - PEER-TO-PEER COMMUNICATIONS BETWEEN PROCESSORS ALLOWS USE OF OFF-THE-SHELF LAN TECHNOLOGY
 - SUBSYSTEM PROCESSORS MAY REQUIRE ADDITIONAL SOFTWARE AND INTERFACE BOARDS OR SEPARATE NETWORK INTERFACE UNITS FOR EQUIPMENT WITHOUT CURRENT CONTROLLER/MONITOR
 - ROLE OF CENTRAL PROCESSOR WILL DETERMINE EXTENT OF SOFTWARE CHANGES TO SUBSYSTEM PROCESSORS
 - SUBSYSTEM PROCESSORS PROVIDE EQUIPMENT INTERFACES
 - REPRESENTS EVOLUTIONARY EXTENSION OF EXISTING CONTROL/STATUS COMMUNICATION CAPABILITIES

This use of subsystem processors represents an evolutionary approach to the integration of terminal subsystems, allowing the central processor to assume a range of responsibilities. Furthermore, by delegating the problem of interfacing to particular equipment units to the various subsystem processors, the control and status LAN implementation is simplified, allowing use of off-the-shelf technology. Almost any of the available local area network options would be appropriate, the choice depending on a more detailed understanding of the future subsystem and central processor functions than is currently available.

Classified/Unclassified Data

As discussed in regard to the full intercommunications LAN, DSCS network configuration data is classified and requires special treatment. While the communication of individual control and status information between equipment units and processors as discussed here is unclassified, the central and subsystem processors, however, do handle classified information. The processors themselves may be split into red and black entities, the black processors tied to the control and status LAN, or, alternatively, Line Guardian Units may be introduced to insure that all information on the local area network is unclassified.

The local area network may be required, however, to support the communication of classified data, one possibility being the support of communications between the earth terminal processors and DOSS, the DSCS Operations Support System. To fulfill security requirements, either two separate local area networks are needed or a single local area network composed of two distinct physical segments with the interconnection protected by a Line Guardian Unit is required. The actual design again depends on the signal flows and connectivities to be supported by the local area network.

Observations

From the above discussion, it is clear that a control and status local area network for the DSCS earth terminals is feasible. The specific design and implementation of such a local area network, however, depends on the connectivity and signal flows which must be supported. Two design approaches have been identified, each reflecting different roles for the terminal's control and status monitor processors. If the control and status LAN is restricted to the support of mostly processor-to-processor communications, the number of LAN connections is then significantly few and the cost of the LAN itself becomes minimal. If, on the other hand, all terminal equipment is to be connected to the control and status LAN, then the cost of the NIU's per terminal approaches much higher levels. In general, however, the intercommunication of control and status signals is consistent with the type of communications currently supported by local area networks, implying that commercially available, cost-effective LAN options may be employed.

SECTION 6

APPLICATION OF DIGITAL SWITCHING TECHNOLOGY
TO DSCS SUBSYSTEM INTEGRATION

6.1 INTRODUCTION

As discussed in Section 3, DSCS earth terminals provide the communications equipment needed to support end-to-end satellite communications of user circuits with data rates from 75 bps up to 10 Mbps. Integration of the earth terminal equipment and subsystems involves the establishment of communications connectivities between devices and the connectivities required to support control and status monitoring of the terminal equipment. While the previous section investigated the application of local area network technology to provide these connectivities, an alternative method of accomplishing equipment intercommunication is through the use of digital switching. Digital switching capabilities have been developed in response to the need for rapid circuit switching under automatic control, especially as required by the telephone industry. This section, then, discusses the application of digital switching technology to the DSCS earth terminal integration problem.

The general digital switching concept as applied to DSCS earth terminals is illustrated in Figure 6-1. In addition to the three earth terminal equipment groups and the equipment control and monitoring capability, an electronic patching function between each group of equipment allows any of the outputs of one equipment group to be routed, via central control, to any of the inputs of the next group of equipment. Although not shown in Figure 6-1 switching among equipment within the same group is also possible. This switching capability allows for any arbitrary equipment configuration to be established by a central control capability. The switching capability described here can enhance DSCS terminal integration by allowing dynamic user circuit switching through the terminal, dynamic circuit rerouting to avoid failed equipment, automatic configuration status

and bookkeeping, and remote control. Several issues arise from the use of electronic patching in this way. The three patches shown in Figure 6-1 will, typically, support signals of increasing bandwidth, from baseband to IF. The patch from the user signals must support user signals of all rates; the patch from the multiplexer group to the modem group must typically support higher rate baseband signals (i.e., multiplexed user signals); and the patch between the modem group and the RF group must support modulated signals at IF. In addition, the electronic patch must maintain a high degree of reliability since without redundant patches it represents a single point failure for the terminal.

Given the DSCS integration requirements, the general digital switching concepts, and the issues related to digital switching in DSCS terminals, this section discusses the use of a specific digital switching system currently being developed for use in military communication systems: the Integrated Multiplex, Patch, and Test (IMPAT) developed by Martin Marietta. The following sections present a description and general applications of the IMPAT, followed by a discussion of IMPAT capabilities in the DSCS earth terminals and concluding with the application of the IMPAT to the baseline terminal discussed in Section 3, including an IMPAT sizing for the application.

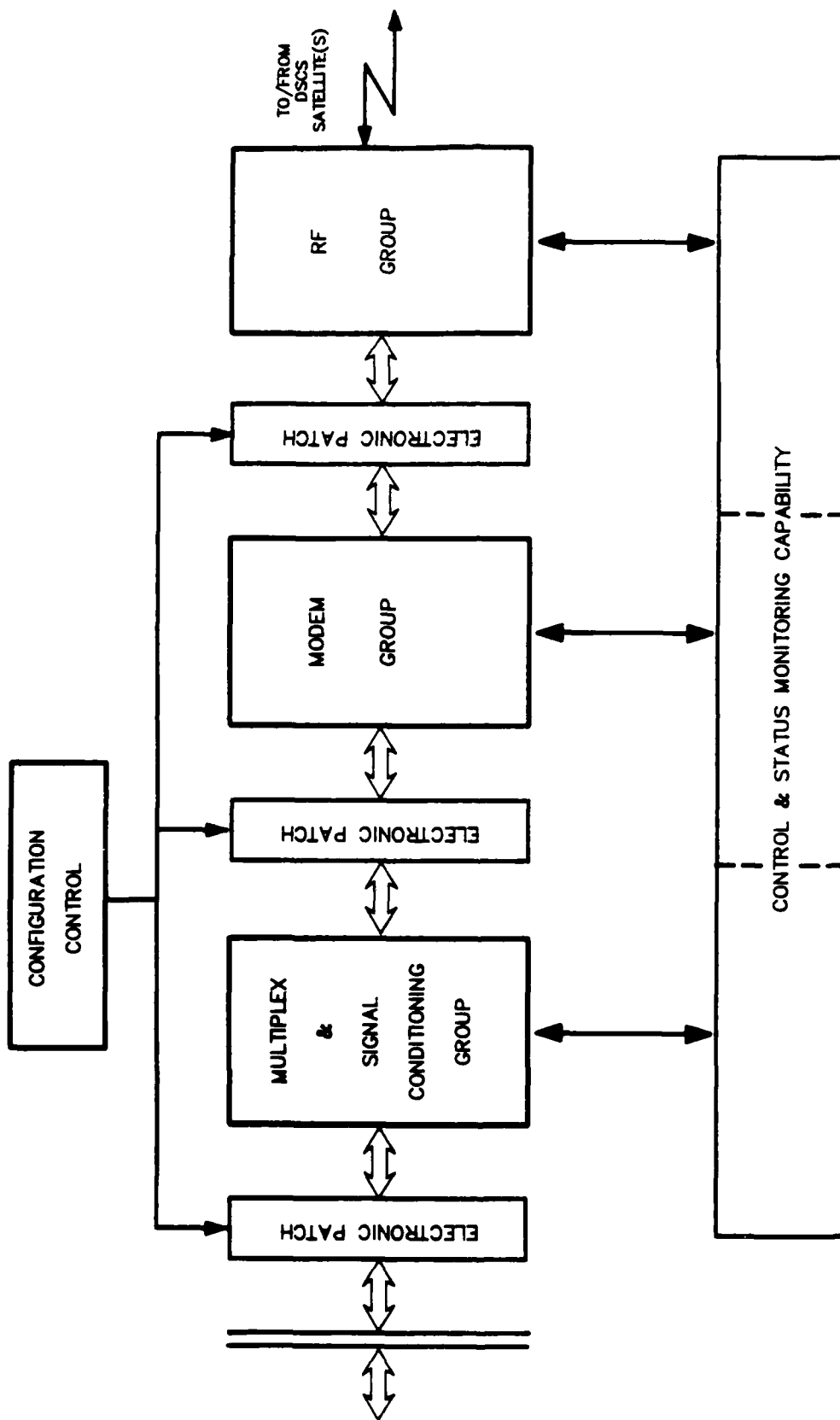


FIGURE 6-1: DIGITAL SWITCHING CONCEPTS APPLIED TO DSCS TERMINAL EQUIPMENT

6.2 IMPAT DESCRIPTION

The Integrated Multiplex, Patch, and Test is a modular electronic patch and multiplexer system employing microprocessor control and built-in test capabilities. The IMPAT provides switching control through electronic patching, a wide variety of configurable multiplexer formats, and high reliability through self-test and failover features. This section discusses the IMPAT's support of DSCS user circuit connectivities and associated features, control and monitoring capabilities, some generic applications, and finally reliability and availability issues. Since the IMPAT design is flexible, its current capabilities do not necessarily limit future IMPAT applications. Both current and future IMPAT characteristic data are provided in detail in Appendix A.

Communication Characteristics

In supporting communication circuits, the IMPAT comprises multiplexer and demultiplexer cards, electronic patch circuits, user signal I/O cards (8 channels each), nonvolatile memory units, and a central processor. These modular components allow any combination of user I/O and multiplexer access to the electronic patch. IMPAT is modularly configured for a particular application, where the basic IMPAT module provides 96 channels consisting of one matrix card and up to 12 user I/O, multiplexer or demultiplexer cards (any combination of 12). Expansion modules can be added in two-module increments---up to 16 total---bringing the total capacity up to 1536 channels. The minimum configuration provides 96 channels in one chassis. The single rack configuration provides up to 480 channels, while the maximum 1536 channel configuration requires three racks.

Each IMPAT user I/O card supports eight channels of various programmable user interfaces including CVSD and PCM up to 64 Kbps. The electronic patch is implemented using a time division multiplexing scheme on a multiple channel 72 kbps internal data bus. Current implementations use one channel of the internal bus per patch channel, thereby limiting the maximum rate to 72 kbps. Future developments will exploit a technique employing several

bus channels per patch channel, thus allowing rates of over 1.5 Mbps. The multiplexer/demultiplexer cards are capable of emulating a host of existing multiplexer formats including the LRM, FCC- 98, and GSC-24.

Control and Status Monitoring

The IMPAT provides three levels of control and monitoring capability: front panel, remote, and the IMPAT mode telemetry channel. The front panel interface comprises a sixteen key key-pad and alphaneumeric display through which the operator can generate and display configuration data, display alarm and status data, and perform analog and digital testing. Similarly, all front panel control operations are executable from the remote control interface (RS-232 and RS-422; up to 9600 baud). A remote terminal or processor interface to the IMPAT permits printing, data base generation, and other software aids to expedite IMPAT configuration and performance monitoring. Multiplexer operation with the IMPAT framing format provides an in-band telemetry channel on the composite signal allowing control and monitoring via the composite channel. The telemetry capability permits initialization of tests, monitoring of test results, and system status monitoring. In addition, the telemetry channel can be used for system reconfiguration by initiating a transfer of data stored in the backup memory to the on-line memory.

IMPAT Applications

Based on the above discussion of IMPAT technical capabilities, Figure 6-2 illustrates some general IMPAT operational applications. With user I/O cards only, IMPAT can be configured as an electronic user patch panel, where user signals of various formats enter the patch, are routed, and exit the patch in various user formats. IMPAT configured with mux/demux cards only provides a composite channel reassignment function. This application may facilitate network control by providing a controllable node capable of individual user circuit reassignment in a single unit. Of course, any combination of multiplexer and user I/O cards is possible, resulting in a

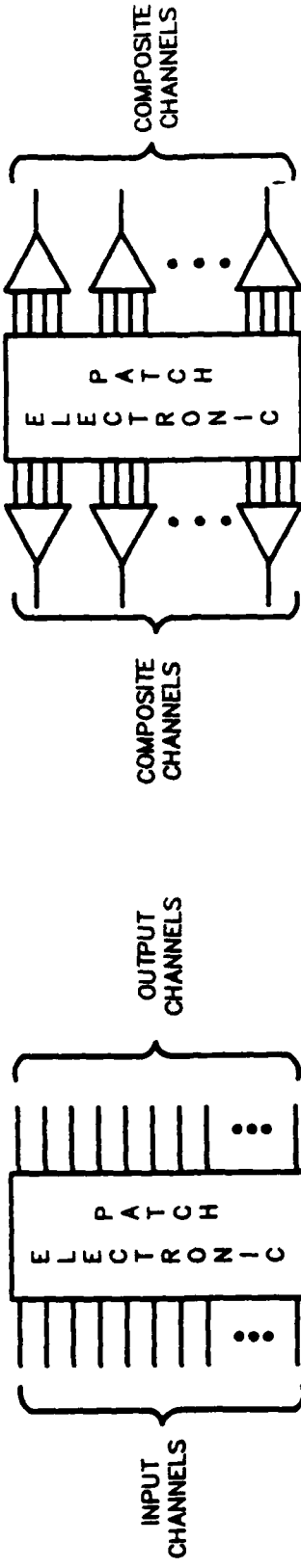
variety of configurations including the traditional patch and multiplex configuration. Cascaded multiplexing may also be accomplished with IMPAT by wiring a multiplexer output to the electronic patch input as a user signal, as long as the multiplexer output is compatible with a user I/O format available on the IMPAT. This type of configuration can be envisioned to establish a fully controllable configuration of baseband equipment.

Availability/Reliability

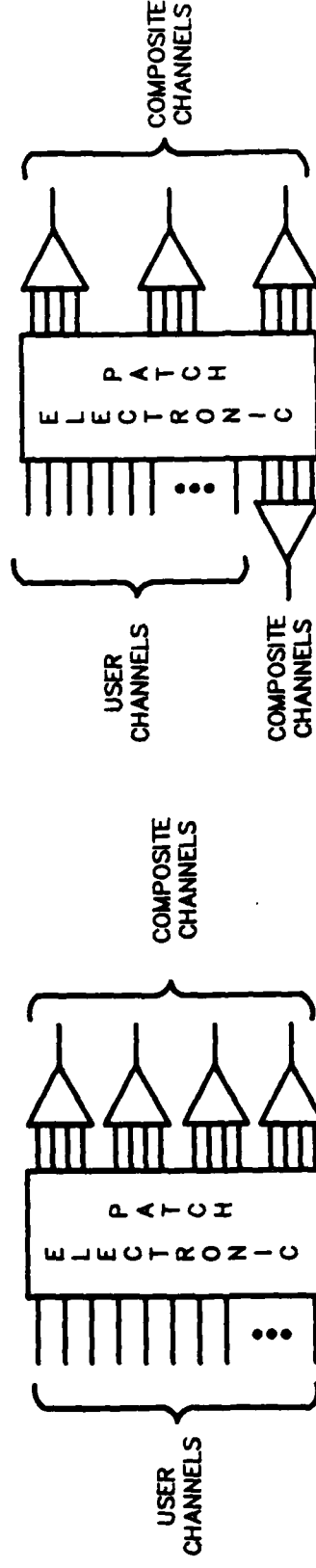
In addition to the communication, control, and status monitoring capabilities, the IMPAT provides several reliability features. The fact that the IMPAT would consolidate the functions of various equipment into a single unit, leaving an earth terminal vulnerable to a single point failure in the IMPAT unit, necessitates the requirement for high reliability of the IMPAT. The IMPAT provides diagnostics comprising user interface, framing, timing, and hardware monitoring and built-in analog and digital testing. The IMPAT configuration includes redundant components and provides the capability, under microprocessor control, to detect failed components and switch to redundant components or circuits. Similarly, the IMPAT can be used to switch from failed to redundant equipment external to the IMPAT. A terminal control processor is envisioned which would detect an equipment failure and command the IMPAT to switch the failed equipment input to that of a spare. Network availability may also be enhanced by the IMPAT's quick rerouting capability, allowing reconfiguration of a network to adapt to stressed conditions. Finally, the operational configuration data of the IMPAT is stored in its nonvolatile memory where it can be used to restore the terminal configuration in the event of a disruption.

Observations/Comparisons

Along with the information provided in this section, it may be helpful to put the IMPAT's capabilities in perspective by comparing them to those of the equipment which the IMPAT might replace. The IMPAT's electronic patch function replaces the manual patch panel in current terminal configurations. Although the IMPAT patch is fully and remotely controllable, being an active device it is subject to failure. The IMPAT multiplexer function

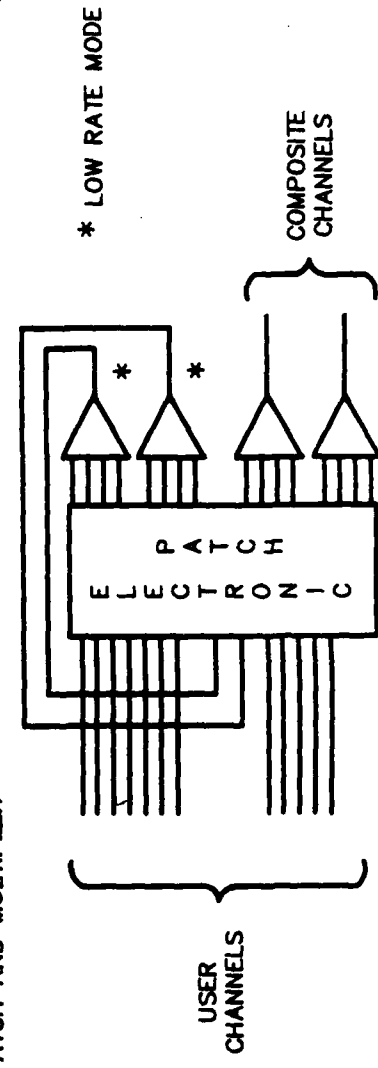


CHANNEL REASSIGNMENT



PATCH AND MULTIPLEX

HYBRID REASSIGNMENT/MULTIPLEX



CASCADED MULTIPLEXING

FIGURE 6-2: IMPAT CONFIGURATIONS

saves a considerable amount of space and power consumption since the multiplexers are implemented on cards instead of an entire rack chassis, as is the case with existing multiplexers.

It should be noted that the IMPAT characteristics described here are not all under the current IMPAT development contract but are being considered for future implementations. The IMPAT multiplexers can emulate a variety of existing multiplexer framing formats; however, because of the patch channel rate limitation, it does not always perform the identical function of these multiplexers. For example, the GSC-24 accepts inputs up to 3 Mbps; the current IMPAT, emulating the GSC-24, only accepts inputs up to 64kbps. Details of the proposed IMPAT capabilities and those currently under contract are provided in Appendix A.

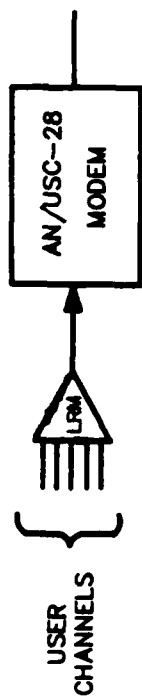
6.3 USE OF IMPAT IN THE DSCS EARTH TERMINALS

Based on the IMPAT capabilities discussed in the previous section and the intercommunication requirements of the DSCS earth terminals, several uses of IMPAT to support DSCS terminal intercommunications are evident. Two types of intercommunication are treated separately: support of the user communication circuits and the consolidation of control and monitoring signals within the earth terminal.

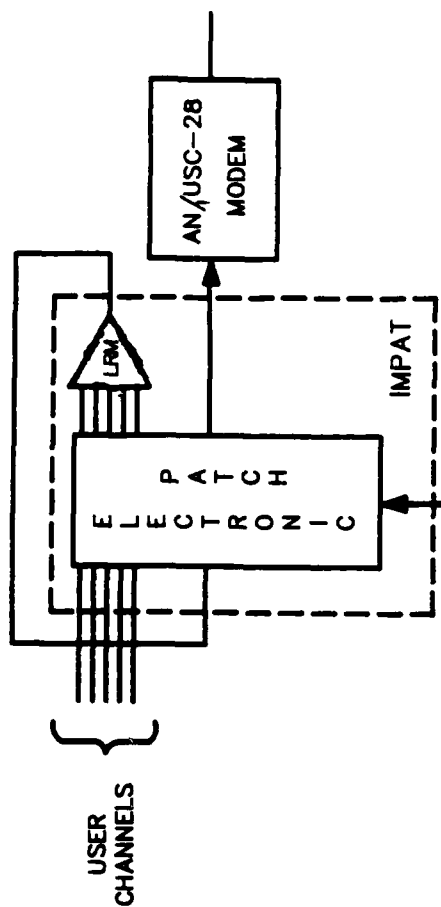
The use of IMPAT to provide communications connectivities in support of DSCS user signals is presented through a discussion of how IMPAT may establish the typical baseband equipment chains of Section 3. Figure 6-3 illustrates the implementation of specific equipment chains using IMPAT by comparing the current DSCS configuration with an equivalent IMPAT configuration approach. Note that IMPAT's electronic patch function allows controlled switching between all baseband equipment, while its multiplexer function allows replacement of the individual multiplexers. This concept of baseband equipment chains is generalized in Figure 6-4.

In the configuration of Figure 6-4, all user signals access the baseband equipment via the IMPAT electronic patch. Similarly, all baseband equipment outputs connect to other equipment via the electronic patch. When a given signal is ready to be modulated it is again passed through the electronic patch and then on to the modems. This configuration provides maximum connectivity and flexibility since the electronic switch provides the connection between each equipment pair. Such a switching capability allows for circuit rerouting within the terminal in the event of an equipment failure, as well as rerouting in the network (if all terminals are appropriately equipped) for network reconfiguration or for adaption to stressed environments. This application of IMPAT also results in a somewhat standardized terminal wiring scheme, since equipment in every earth terminal is connected to the IMPAT in the same way. Since the configuration of the IMPAT determines the terminal configuration, unique configurations can be implemented through the IMPAT configuration which may be generated via software.

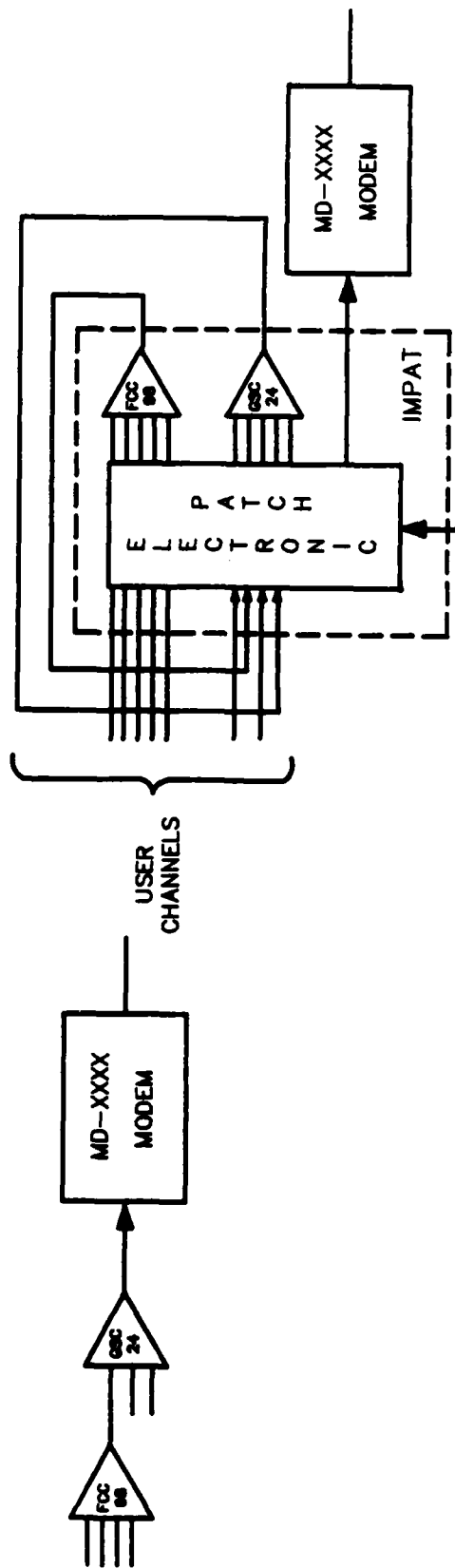
CURRENT DSCS CONFIGURATIONS



EQUIVALENT IMPAT CONFIGURATION



CONTROL



CONTROL

FIGURE 6-3: IMPAT APPLICATION TO EQUIPMENT CHAINS

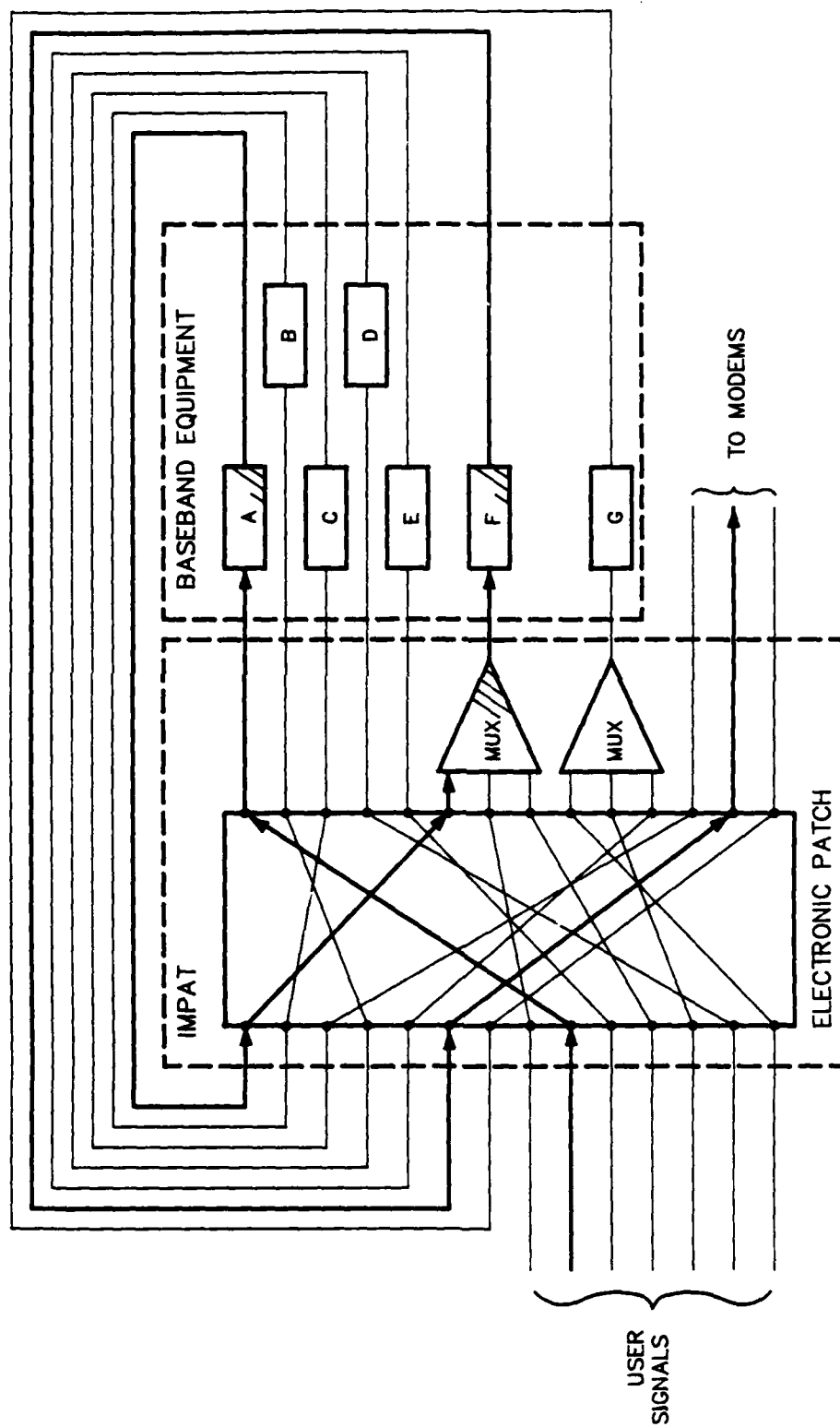


FIGURE 6-4: IMPAT ESTABLISHMENT OF BASEBAND EQUIPMENT CHAINS

Although the concept of IMPAT establishing baseband equipment chains appears beneficial, several requirements must be imposed on the IMPAT to realize the concept. The IMPAT must support, via user interfaces, the transmission of the highest data rate signal in the terminal, which may be on the order of 6 Mbps. The IMPAT configuration currently under contract, however, cannot accept inputs greater than 64 kbps. As noted in the previous subsection, the ability to support higher data rates is expected to be available in future versions of IMPAT.

The second type of connectivity which must be provided for earth terminal integration is that which supports the communication of control and status monitoring information between earth terminal devices and a central controller/monitor. The configuration of Figure 6-5 suggests the concept of IMPAT providing a centralization of equipment control and status monitoring signals. Equipment control and status monitoring interfaces are routed through the electronic patch to a multiplexer which interfaces directly with the controller/monitor processor. The IMPAT in this application would additionally provide the ability to switch control from a failed control/monitor processor to a redundant processor.

In order for IMPAT to provide the control and status monitoring capability described above, it must have user I/O interfaces compatible with the equipment control and monitor interfaces. The IMPAT must also provide a multiplexing format which is amenable both to the equipment signals and the central processor interface.

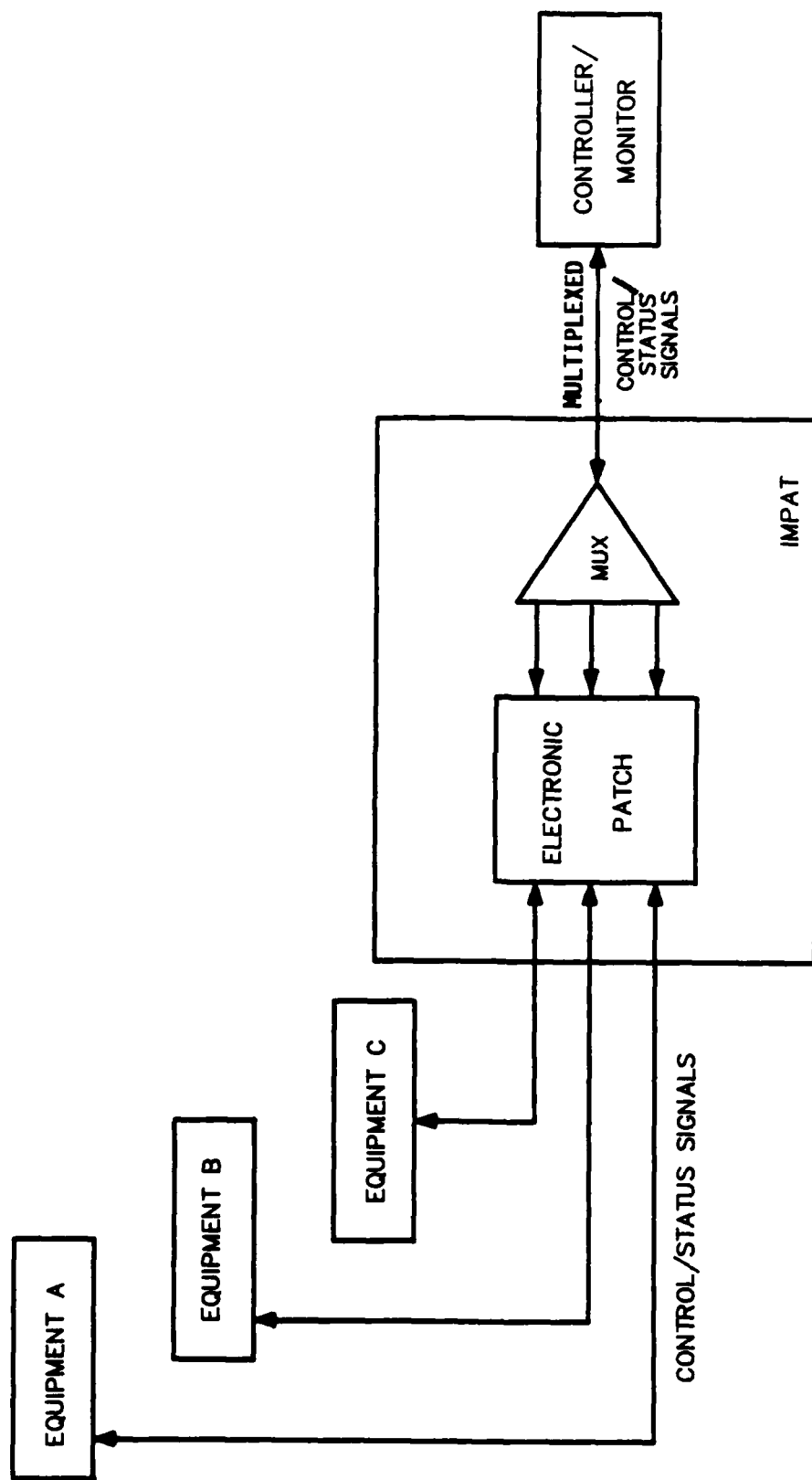


FIGURE 6-5: IMPAT REGULATION OF CONTROL & STATUS SIGNAL FLOW

6.4 USE OF IMPAT IN BASELINE DSCS EARTH TERMINALS

The previous section discussed various ways in which the IMPAT may support the user communication and control and status monitoring connectivities required for DSCS earth terminal integration. To provide a concrete example of integration using IMPAT and a basis for sizing, this section presents the application of IMPAT to the baseline terminals discussed in Section 3. Two configurations are presented with an IMPAT sizing for each. The first example reflects the use of IMPAT beyond its current capabilities, employing the IMPAT architecture to the fullest. The second example provides a configuration which reflects only the IMPAT capabilities which are currently under contract to be provided by Martin Marietta. The following discusses the sizing methodology for the case of a baseline light DSCS earth terminal.

The first configuration of Figure 6-6 is a specific example of IMPAT establishing baseband equipment chains as in the generic configuration of Figure 6-4. All signals entering the patch are routed either to one of the IMPAT multiplexers or directly out to the modems through user I/O. Multiplexer outputs are fed back to IMPAT user I/O interfaces. Of course, this configuration assumes that the IMPAT is capable of accepting multiplexer outputs and high rate user signals as inputs through the user I/O cards. The modem and RF equipment configuration is unchanged from the baseline terminal of Section 3.

To estimate the size of the IMPAT needed to fulfill the requirements for communication in this terminal, the number of multiplexer cards, demultiplexer cards, user I/O ports, and patch channels must be calculated. Since the circuits are assumed to be full duplex, a multiplexer and demultiplexer card is required for each multiplexer in Figure 6-6. Each multiplexer output feeds back to a user I/O port, each modem connects to an I/O port, and each user circuit connects to an I/O port. The total number of multiplexer, demultiplexer, and user I/O (8 ports each) including 1 for 4 redundancy determines the number of IMPAT

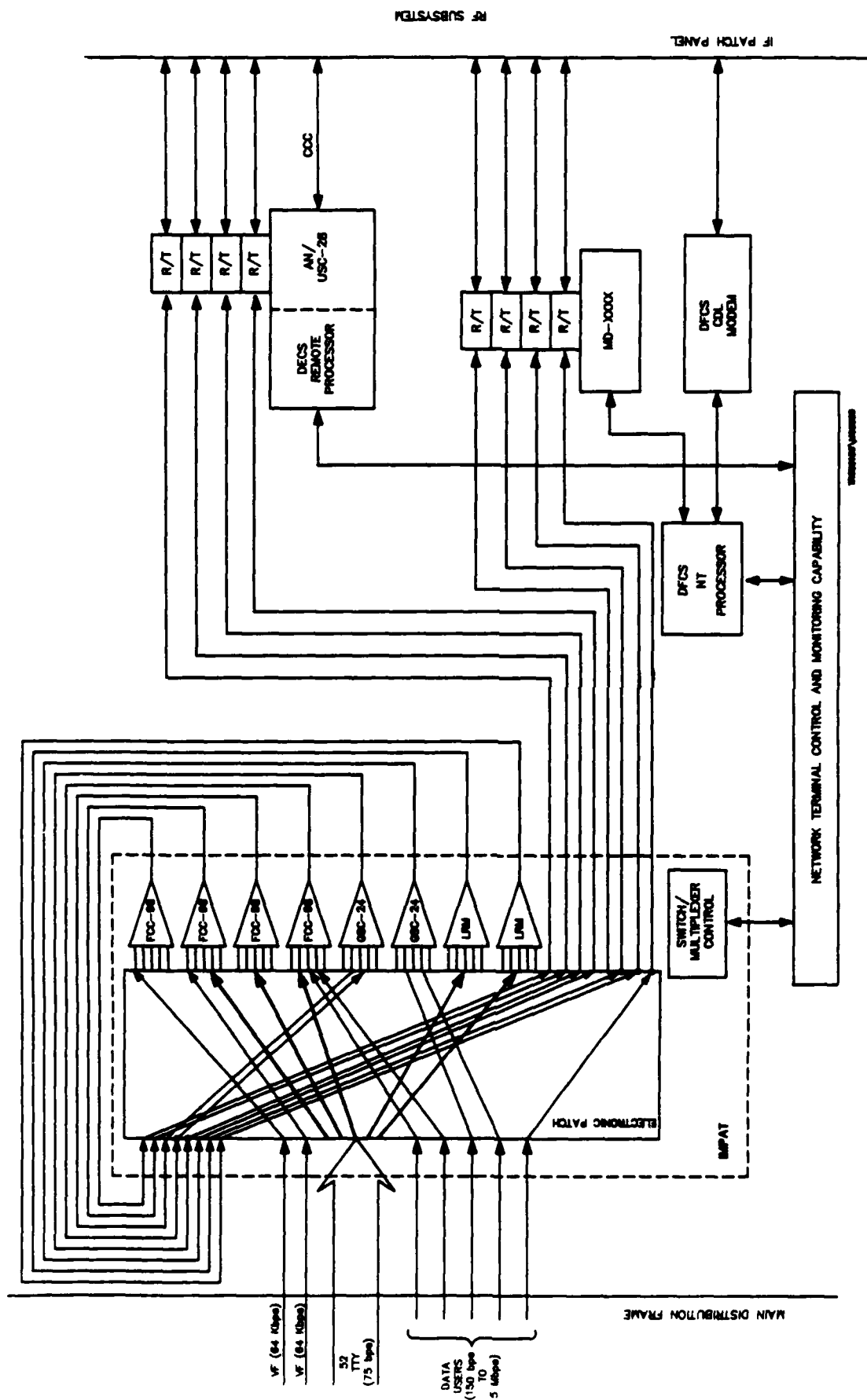


FIGURE 6-6: NETWORK TERMINAL CONFIGURATION WITH INPUT

modules required (12 cards per module). In addition, each IMPAT module provides 96 patch channels---if this does not meet the maximum number of interfaces on one side of the patch, additional modules are required. The minimum IMPAT configuration contains one module, a single rack contains three to five modules, and additional racks may contain up to six modules where the maximum is 16. Table 6-1 presents the sizing for the configuration of Figure 6-6.

The second IMPAT configuration illustrated in Figure 6-7 involves only the current capabilities of IMPAT. Signals entering the electronic patch of the IMPAT are restricted to 64 kbps or less, and multiplexer outputs are not fed back into the IMPAT user I/O ports. In this configuration the IMPAT provides an electronic patch only for those users less than 64 kbps and replaces only the first stage of multiplexers. The second stage of multiplexers must be provided externally.

The IMPAT sizing for this configuration is similar to the previous sizing with the following modification. The multiplexer cards needed are twice the number of first stage multiplexers, and the user I/O ports required is equal to the number of user signals with rates less than 64 kbps. Table 6-2 shows the calculated sizing for the configuration of Figure 6-7.

The sizing methodology explained above was used along with the data provided in Tables 3-1 and 3-2 to estimate the IMPAT requirements, reflecting current and extended IMPAT capabilities, for the medium and heavy terminals as well as the light. The results are summarized in Table 6-3.

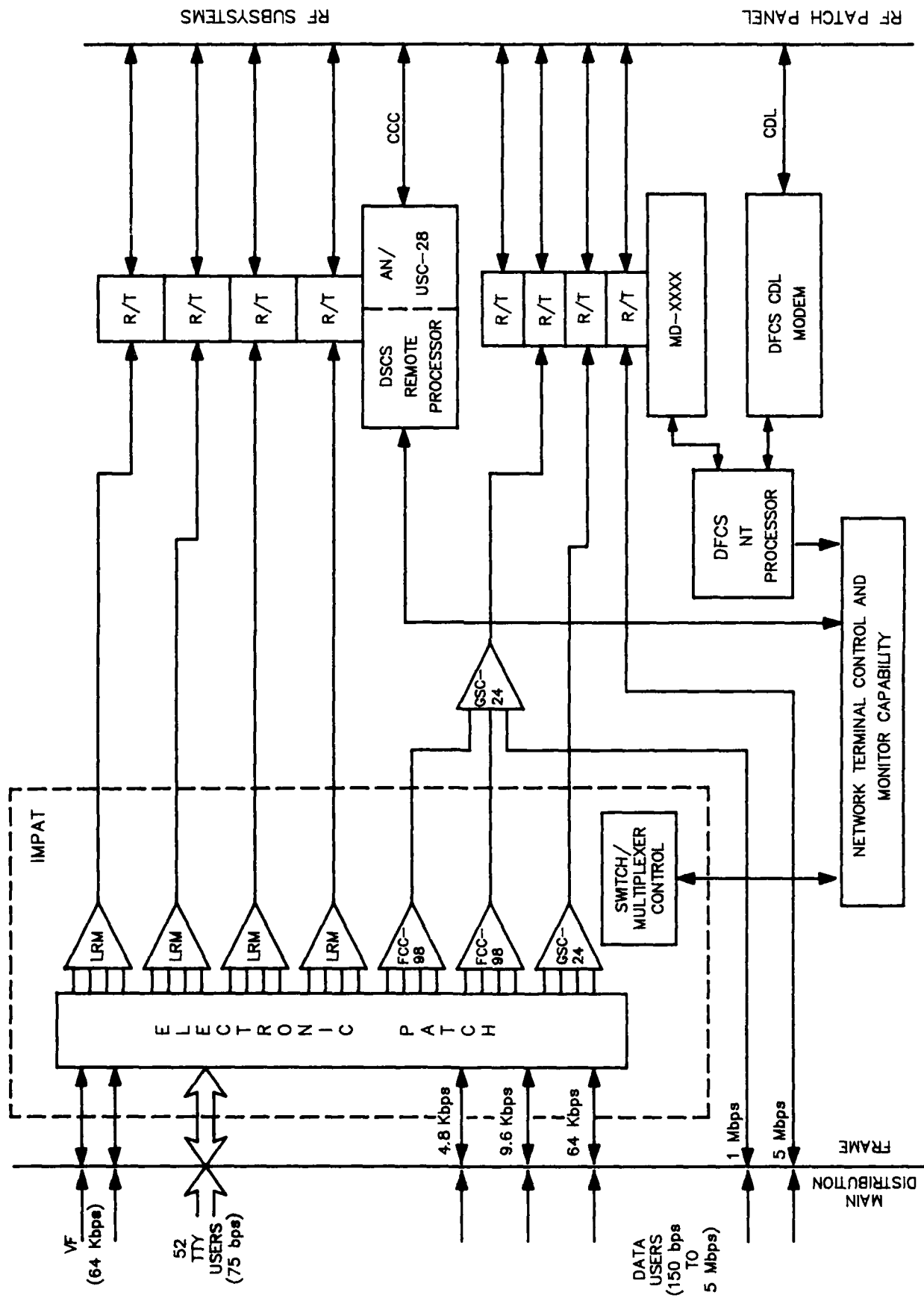


FIGURE 6-7: NETWORK TERMINAL CONFIGURATION WITH IMPAT (CURRENT CAPABILITY)

TR650156 V400391

TABLE 6-1
IMPAT SIZING (EXTENDED CAPABILITY)

MUX CARDS

8 MUX



1 FOR 4 REDUNDANCY



10 MUX

8 DEMUX

10 DEMUX

20 CARDS TOTAL

USER I/O CARDS

8 PORTS FOR MUX OUTPUT

69 PORTS FOR USER INPUT

8 PORTS FOR OUTPUT TO MODEM

85 TOTAL PORTS

8 PORTS/CARD



11 CARDS

1 FOR 4 REDUNDANCY



14 CARDS

PATCH CHANNELS

USERS INPUT 69

INPUT FROM MUX OUTPUT 8

TOTAL REQUIRED CHANNELS 77

REQUIRED IMPAT CONFIGURATION

10 MUX

10 DEMUX

14 I/O

34 CARDS



12 CARDS PER MODULE



3 MODULES

3 MODULES PROVIDES 288 CHANNELS

1 IMPAT BASIC MODULE WITH A 2 MODULE ADDITION FITS IN ONE RACK WITH ROOM
FOR 2 MORE MODULES.

TABLE 6-2

IMPAT SIZING (CURRENT CAPABILITY)

MULTIPLIER CARDS

7 MUX	⇒	1 FOR 4 REDUNDANCY	⇒	9 MUX
7 DEMUX				<u>9</u> DEMUX
				18 CARDS TOTAL

USER I/O CARDS

69 PORTS FOR USER INPUT

8 PORTS PER CARD	⇒	9 CARDS
1 FOR 4 REDUNDANCY	⇒	11 CARDS

PATCH CHANNELS

USER INPUTS	69
-------------	----

REQUIRED IMPAT CONFIGURATION

9 MUX	⇒	12 CARDS PER MODULE	⇒	3 MODULES
9 DEMUX				
<u>11</u> I/O				
29 CARDS				

3 MODULES PROVIDES 288 CHANNELS

SINGLE RACK 3 MODULE CONFIGURATION; ALLOWS ROOM IN RACK FOR 2 ADDITIONAL MODULES.

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TABLE 6-3

IMPAT SIZING SUMMARY
CURRENT / EXTENDED IMPAT CAPABILITY

IMPAT COMPONENTS		BASELINE TERMINALS		
		LIGHT 6.24 MBPS	MEDIUM 12.41 MBPS	HEAVY 37.46 MBPS
MULTIPLEXER CARDS REQUIRED		14/16	46/60	40/66
MULTIPLEXER CARDS REDUNDANT		4/4	12/16	10/18
USER I/O CARDS REQUIRED		9/11	36/43	48/61
USER I/O CARDS REDUNDANT		2/3	9/11	12/16
PATCH CHANNEL REQUIREMENTS		69/77	281/319	381/423
IMPAT CONFIGURATION	MUX CARDS	9/10	29/38	20/42
	DEMUX CARDS	9/10	29/38	20/42
	USER I/O CARDS	11/14	45/54	60/77
	CHANNELS AVAILABLE	288/288	864/1152	864/1344
	#IMPAT MODULES	3/3	9/12	9/14
	#IMPAT RACKS	1/1	2/3	2/3

APPENDIX A

DCSS EQUIPMENT DOCUMENTATION

This appendix contains a list of equipment employed in the Digital Communications Subsystem (DCSS) of the DSCS earth terminals. Based on available documentation associated with the equipment, information is compiled here which pertains to the communication, status and control information transfer among the equipment in an earth terminal. The communication, control, and status connectivities as well as interfaces are provided to the extent that information was available for each set of equipment.

A-1 AN/USC-28 MODEM

Advanced spread spectrum satellite communications modulator/demodulator. Used in DSCS terminals for the modulation and demodulation of ECCM user circuits. Operation in: spread spectrum AJ and mitigation modes, TDMA or TDM modes, voice and graphics modes. Also provides ECCM network information from all NT's to the USC-28 at the NCT which interfaces to the ECCM Controller computer to provide centralized network control of the ECCM network. Each modem consists of a central controller and up to 15 receive/transmit (R/T) units.

Connectivities:

- Communications:
 - Inputs:
 - AJ critical control circuit teletype orderwire
 - Up to 15 AJ digital data channels 75 bps to 2.5 Mbps
 - One 75 bps orderwire for each digital channel
 - Interface to KY-801 codec 75 bps to 2.5 Mbps
 - Interface with KY-883 codec 75 bps to 100 Kbps.
 - Outputs:
 - 70MHz or 700MHz interface to SHF terminal.
- Control and Status:
 - Status Monitoring if output to a display terminal associated with the modem
 - Control and status information is passed through the network (via CCC) to the NCT from all USC-28 modems in the network.

Interfaces:

- Control and Status:
 - USC-28 interfaces to ECCM control computer via IEEE 488 GPIB port at 2400 baud.

A-2 MD-XXXX MODEM

Non-ECCM offset QPSK/BPSK modem with forward error correcting coding/decoding. For modulation of non-ECCM user signals. Operates in the following modes: BPSK with no FEC coding, BPSK with rate 1/2 or 3/4 FEC coding, OQPSK with no coding, OQPSK with rate 1/2 or 3/4 FEC coding. Each modem set consists of a master controller module and several receiver and transmitter modules (up to sixteen total per control module). The minimum configuration is one receiver module, one transmitter module and one control module.

Connectivities:

- Communications:

- Inputs:

- Clock and data input for each receive/transmit module.

	BPSK	OQPSK
no coding 16kbps to	10 Mbps	20 Mbps
rate 1/2 16kbps to	5 Mbps	10 Mbps
rate 3/4 16kbps to	7.5 Mbps	15 Mbps

- Compatible with AN/FCC-98, AN/GSC-24, MD-1002/G, MD-920 /G, LRM, KY-801, KG-81 and others.

- Outputs:

- 70MHz CW, OQPSK, or BPSK with filtering.

- Control and Status:

- For each set control and status for each of the transmit receive modules is handled through the control module

- Each receive module has an interface to the ALPC. (soft decision, timing, and Es/No)

- Each control module has an interface to a remote controller.

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Interfaces:

- Communications:
 - Data and clocks -- Bendix 34105-1 connector
 - IF -- TNC-type connector.
- Control and Status:
 - ALPC interface -- RS-449
 - Remote Control -- RS-449.

A-3 INTEGRATED MULTIPLEX PATCH AND TEST (IMPAT)

IMPAT functionally replaces a digital matrix switch followed by a set of multiplexers. The equipment includes a controllable electronic patch, programmable multiplexers, a control processor, self testing facilities and an operator interface. IMPAT accepts and outputs user signals in digital, analog to PCM, analog to CVSD, and FSK to digital compatible with TRI-TAC, GSC-24, TD-1069, TD-660, T1 (FCC-98), and NATO. The IMPAT currently under contract to Martin Marietta has limited capabilities; the design, however is flexible and capability upgrades are expected. The data below reflects Martin Marietta's expectations of the ultimate IMPAT implementation. A second set of data applies to the version of IMPAT which is currently being developed under contract.

Ultimate IMPAT Configuration

Connectivities:

- Communications:
 - User signals (user I/O ports):
 - Analog to PCM 48 / 64 kbps
 - Analog CVSD 16 / 64 kbps
 - Digital up to 1.5 Mbps (future)
 - 96 patch channels per module, can be increased to 96 x 16 in increments of 96 composite signals (multiplexer outputs):
 - Composite Signals (Multiplexer Outputs):
 - Up to 3 Mbps (future).
- Status and Control:
 - Controlled by central processor and operator terminal
 - Remote control for all front panel operations
 - Audio and visual alarms
 - Telemetry channel for remote configuration status and test via the composite channel.

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Interfaces:

- Communications:
 - Compatible with TD-754, KG-27, KG-81, KG-84
- Control and Status:
 - Remote control via serial RS-449 interface operating at 110 to 9600 bps
 - Remote alarms via separate connector (relay type alarms).

IMPAT Configuration Under Contract

● Hardware Configuration:

- Single rack
- 3 multiplexer; 3 demultiplexer cards
- 8 digital user I/O cards
- 2 CVSD user I/O cards
- 3 switch matrix cards
- 2 nonvolatile memory cards
- 1 microprocessor card.

● Multiplexer Emulation:

- FCC-98
- GSC-24 (inputs less than 64 kbps; 15 channels; aggregate up to 1 Mbps)
- TD-1235
- TD-660
- TD-1069
- NATO 30 channel PCM format.

A-4 AN/FCC-98 MULTIPLEXER

Multiplexer/Demultiplexer performs analog to digital conversion (PCM) of up to 24 (4 kHz) voice channels and time division multiplexing to form the aggregate channel. Voice channel cards can be replaced by 50 kbps data cards. This multiplexer typically precedes a GSC-24(v) multiplexer.

Connectivities:

- Communications:
 - User signals:
 - 24 voice or data channels up to 64kbps per channel
 - Composite signals:
 - Compatible with following equipment:

	Rates (kb/s)
KG-81	192, 384, 768, 1544
AN/GSC-24	192, 384, 768, 1544
VICOM 4000-02	1544

- Status and Control:
 - Audio-visual alarms, remote and front panel
 - Control from front panel only.

Interfaces:

- Communications:
 - Voice channel input full duplex 4 wire
 - Full duplex data channels.
- Control and Status:
 - Remote alarms use relay switches.

A-5 LOW RATE MULTIPLEXER (LRM)

Low rate adaptive time division multiplexer/demultiplexer. Up to twelve duplex channels of digital, FSK, or voice frequency (CVSD conversion) at rates up to 56 Kbps per channel with a maximum aggregate rate of 256 Kbps. The LRM is replacing the GSC-24 in equipment chains supporting ECCM circuits.

Connectivities:

- Communications:
 - Demultiplexed signals:
 - 12 duplex channels; digital, FSK VF (CVSD)
 - Up to 56 kbps
 - Any combination of rates and types
 - 8 channels all at 16 or 32 kbps for Loop Group Modem (LGM) mode.
 - Composite signals:
 - Maximum rate 25kbps
 - Compatible with LGM, AN/GSC-24 and others
 - 128 or 256 kbps for LGM mode.
- Status and Control:
 - Remote control
 - Additional demultiplexed channel for control.

Interfaces:

- Control and Status:
 - Remote control interface; 150 - 9600 baud; RS-499
 - Interfaces with DECS remote processor via remote control.

A-6 LOW SPEED TIME DIVISION MULTIPLEXER (LSTDM)

Low speed TDM accepts as input and provides as output NRZ or conditioned diphase signals. Typically used in the link between the Technical Control Facility and the Earth Terminal.

Connectivities:

- Communications:
 - Demultiplexed signals:
 - 16 ports of 35 to 32 kbps
 - Synchronous, isochronous or asynchronous
 - Mode changed via modular card replacement.
 - Multiplexed signals:
 - Rates (including overhead) of 1.2 to 256 kbps
 - Synchronous, isochronous or asynchronous.
- Status and Control:
 - Remote alarms (audio and visual type).

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USE OF LAN (LOCAL AREA NETWORK) TECHNOLOGY IN DSCS
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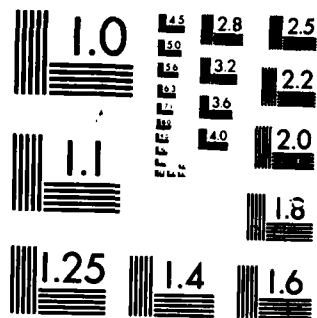
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A-7 AN/GSC-24 MULTIPLEXER

Multiplexer/Demultiplexer accepts high rate digital signals, performs time division multiplexing, and outputs the resulting high rate digital signal. This multiplexer typically accepts inputs from the FCC-98 multiplexer and high rate users (> 100 Kbps). It is being replaced in ECCM circuits by the Low Rate Multiplexer.

Connectivities:

- Communications:
 - User Signals:
 - 24 data channels 50 bps to 3 Mbps
 - Composite signals:
 - Less than 10 Mbps.
- Status and Control:
 - Front panel access only
 - Reconfiguration requires rewiring.

APPENDIX B

COMMERCIAL LAN PRODUCTS

The tables provided in this appendix list by vendor the various local area network products currently commercially available. While the information in the tables does not suffice to provide full descriptions of the products, it does serve to illustrate the variety of products on the market. As can be seen, many vendors provide a range of products with different capabilities, although none provides a product suitable for use as the DSCS terminal full intercommunications LAN. Depending on the design strategy employed, however, any number of the products indicated here might be suitable for use as the DSCS terminal control and status LAN.

The list is somewhat dated, having been compiled from information dating from mid-1985---since that time, IBM has announced its token-ring LAN, FiberLAN (formerly Siecor FiberLAN) has introduced its fiber-optic TDM ring, and other products have entered the market. The products listed here, however, are still currently available and represent the various forms in which possible LAN alternatives are being made commercially available.

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Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
Applitek Corp./ Unilan	broadband	proprietary	1.54M	40,000	30 miles	asynch, synch, IEEE 488, parallel
Unilan	baseband	proprietary	1.54M	1,000	2.5 miles	asynch, synch, IEEE 488, parallel
Unilan	fiberoptic	proprietary	1.54M	1,000	unlimited	asynch, synch, IEEE 488, parallel
AST Research Inc./ AST-PCnet I	baseband	CSMA/CD	800K	223	5,000 feet	PC-specific
AST-PCnet II	twisted-pair	CSMA/CA	800K	160	3,500 feet	PC-specific
Bridge Communications Inc./ Ethernet	baseband	CSMA/CD (IEEE 802.3)	10M	100	2,500m	asynch, synch, IEEE 488
Codenoll Technology Corp./ Codenet-Fiber Optic Ethernet	fiberoptic	CSMA/CD (IEEE 802.3)	10M	1,024	2.8 km	asynch, IEEE 488
Coherent Communications Systems Corp./ Linemate 192	broadband, twisted-pair	transparent format or protocol	19.2K	unlimited	7 miles	asynch, synch, IEEE 488, parallel

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Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
3COM Corp./ EtherSeries Network	baseband	CSMA/CD	10M	1,024	2.5 km	PC-specific
COMTECH Inc./ Cx-Net	twisted-pair, coaxial	Datapoint Arcnet	-	unlimited	-	asynch, synch, X.25, coaxial
Communications, Machinery Corp./ Ethernet	baseband	CSMA/CD (IEEE 802.3)	10M	1,024	2,500m	asynch
Complex Systems Inc./ XLAN	twisted-pair, coaxial (baseband)	CSMA/CA	1M	192	8,000 feet	asynch, parallel, RS232C
Concord Data Systems Inc./ Token/Net	broadband	token-passing	-	5M	-	asynch, synch, RS449, RS422
Corvus Systems Inc./ OmniNet	baseband, twisted-pair	CSMA/CA	1M	64	4,000 feet	PC-specific
CYB Systems Inc./ Unite	baseband, twisted-pair	CSMA/CD (IEEE 802.3)	10M	255	1,500 miles	asynch, synch, parallel

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Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
Data General Corp./ Ethernet	baseband	CSMA/CD	10M	1,024	2,500m	vendor-specific
Multiprocessor Communications Adapter	parallel bus	proprietary	-	4-15	30-140 feet	vendor-specific
Network Bus System (NBS)	baseband	token-passing, proprietary	2M	32	1 mile	vendor-specific
DataPoint Corp./ ARC LAN	baseband	token-passing	2.5M	255	4 miles	asynch
Davong Systems Inc./ Multilink	baseband	token-passing	2.5M	255	22,000 feet	PC-specific
Digital Microsystem Inc./ HiNet	baseband	proprietary	500K	unlimited	7,000 feet	asynch, parallel RS422
Equinox Systems/ Equinox Data PBX	twisted-pair	TDM	9.6K	1,320	2 miles	asynch
Excelan Inc./ Ethernet	baseband	CSMA/CD, (IEEE 802.3)	10M	1,024	500m	bus-specific (e.g., Multibus)
Gandalf DATA INC./ PACXNET	twisted-pair	proprietary	19.2K	2,048	unlimited	RS232C, current loop, MIL-STD-188C, RS449

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Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
Gateway Communications Inc./ G/NET	baseband	CSMA/CD, CSMA/CA	1.43M	255	7,000 feet	PC-specific
IDE Associates, Inc./ IDEAnet	baseband	CSMA/CD	800K	20	2,000 feet	PC-specific
INTECOM Inc./ LANmark Ethernet	baseband, twisted-pair, fiber optic	CSMA/CD (IEEE 802.3)	1M	8,192	54,000	asynch, synch
Interlan Inc./ NET/PLUS	baseband	CSMA/CD (IEEE 802.3)	10M	1,024	2.5km	bus/PC-specific
Intertec Data Systems Corp./ Data Networking System	baseband	polling (proprietary)	3M	255	3,000 feet	PC-specific
Magnolia Microsystems Inc./ MAGnet	baseband, twisted-pair	token-passing	500K	64	2,000 feet	asynch
Metapath Inc./ ROBIN	baseband	ATDM (proprietary)	2M	255	1.5km	asynch, synch, parallel, RS232C

Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
National Instruments/ Net 488	baseband	token-passing	4M	15	2km	IEEE 488
NEC Information Systems Inc./ BRANCH 4670	twisted-pair	CSMA	1M	64	1.2km	asynch, synch, parallel
NESTAR Systems Inc./ PLAN Series	baseband, broadband, twisted-pair, fiber-optic	token-passing	2.5M	255	22,000 feet	asynch, parallel, serial
Northern Telecom Inc. (Data Systems Div.)/ Omnalink	baseband	proprietary	56K	8	40,000 feet	asynch, synch, parallel
Northern Telecom Inc./ SL-1/SL-100 Digital PBX	twisted-pair	-	up to 56K	30,000	40 miles	asynch, synch
Novell Inc./ NetWare	baseband, broadband, twin-ax, twisted-pair, fiber-optic	CSMA/CD, CSMA/CA, token-passing (proprietary)	500K-10M	24 to unlimited	unlimited	asynch, synch, parallel
Orchid Technology/ PCnet	baseband	CSMA/CD	1M	255	7,000 feet	PC-specific

Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
Prime Computer Inc./ PRIMENET/RINGNET	twin-ax, fiber-optic	token-passing	10M	128	3,280 feet	vendor-specific
Proteon Inc./ ProNET	baseband, twin-ax, twisted-pair, fiber-optic	token-passing (IEEE 802.5)	10M	255	50km	bus-specific, asynch
Racal-Milgo Inc./ Planet	baseband	token-passing proprietary	9.216M	500	13 miles	asynch, synch, RS232C
Santa Clara Systems Inc./ PCnet	baseband	CSMA/CD	1M	50	6,000 feet	asynch, IEEE 488, parallel
Siecor Fiberlan/ Net 10	baseband, fiber-optic	CSMA/CD (IEEE 802.3)	10M	1,024	2.5km	vendor-specific
Sytek/ LocalNet 20	broadband	CSMA/CD	120K	-	35 miles	asynch, synch
Tangent Technologies Ltd./ ThinkLink	twisted-pair	proprietary	1M	24	3,000 feet	asynch, synch, parallel

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Company/Product Name	Media	Access Technique	Data rate (bps)	Max. stations	Max. distance	Interface ports
Texas Instruments Inc./ Ethernet	baseband	CSMA/CD	10M	1,024	2,500m	asynch
Ungermann-Bass Inc./ Net/One	baseband	CSMA/CD	10M	1,024	2,800m	asynch, synch, RS232C, IEEE 488
Net/One	broadband	CMSA/CD	5M	1,500	10 miles	asynch, synch, RS232C, IEEE 488
VLSI Networks Inc./ 1553-Net	baseband	CSMA/CD, CSMA/CA	3M	255	8,000 feet	PC-specific
WANG Laboratories, Inc./ WangNet	broadband	CSMA/CD (IEEE 802.3) token-passing, (proprietary)	up to 10M	-	-	vendor-specific
Western Telematic Inc./ RS232C Smart Switch	twisted-pair	-	9600K	16	2,000 feet	asynch, RS232C
Xyplex Inc./ XYPLEX System	broadband, fiberoptic	CSMA/CA	1M	32,000	6 miles	asynch, RS232C
Ztel Inc./ Private Network Exchange (PNX)	baseband, twisted-pair, fiberoptic	token-passing (IEEE 802.5)	4M	250	64km	asynch, synch, RS232C

APPENDIX C

THROUGHPUT REQUIREMENTS FOR
A FULL INTERCOMMUNICATIONS LAN

The objective of this appendix is to produce a reasonable estimate of the requirements of the full intercommunications local area network suggested in Section 5 of this report to support subsystem integration in the baseline light, medium, and heavy terminals. The information required to make such an estimate consists of the number of users and associated data rates, the number of each equipment type, and the number of equipment-to-equipment connectivities and the associated data rates. Based on this information the number of Network Interface Units (NIU) and the cable bandwidth requirements can be assessed. Similarly, the information compiled here can also be used to estimate a sizing of IMPAT capabilities required to support equipment to equipment interconnections in the baseline terminals.

Information gathered here pertains to typical light, medium, and heavy terminals. The MIST is used as the baseline light terminal with the MIST specification as the source of information; the medium and heavy terminals are based on two representative DSCS terminals with information originating from the DSCS Program Plan. The MIST Specification provides all necessary information while the DSCS Program Plan provides ECCM and FDMA user information; however, equipment information is provided only for the ECCM circuits and multiplexer plans are not included. The DSCS Transition and Implementation Plan (TIP), though, does provide FDMA equipment information and multiplexer plans for some of the links. Since the Program Plan and TIP reflect implementation plans devised at different points in time, their information is inconsistent and therefore cannot be readily used in combination. Because of the incomplete and contradictory information available, the number of FDMA equipment and multiplexing plans are estimated with the available information as a basis. The user information provided in Table 3-1 along with ECCM equipment information is

TERMINAL SIZING ESTIMATION

- INFORMATION REGARDING DSCS TERMINAL EQUIPMENT AND USERS PRESENTED IN DSCS PROGRAM PLAN AND TRANSITION IMPLEMENTATION PLAN (TIP) IS CONTRADICTORY AND INCOMPLETE
- USER SIGNAL INFORMATION HAS BEEN OBTAINED FROM THE PROGRAM PLAN
- ECCM EQUIPMENT INFORMATION HAS BEEN OBTAINED FROM THE PROGRAM PLAN
- FDMA EQUIPMENT INFORMATION HAS BEEN OBTAINED FROM THE TIP, SCALED AND APPLIED TO THE PROGRAM PLAN USER DATA
 - MODEM SCALE FACTOR REFLECTS TERMINAL AGGREGATE DATA RATE
 - MULTIPLEXER SCALE FACTOR REFLECTS NUMBER OF USER SIGNALS
- MULTIPLEXER PLANS CONSTRUCTED BASED ON SCALED EQUIPMENT AND USER SIGNAL INFORMATION ASSOCIATED WITH THE BASELINE TERMINALS
- MULTIPLEXER PLANS PROVIDE:
 - EQUIPMENT-TO-EQUIPMENT CONNECTIVITY AND ASSOCIATED DATA RATES
 - NUMBER OF EACH EQUIPMENT REQUIRED

extracted from the Program Plan and used as the basis for sizing the baseline terminals.

The information regarding equipment and multiplexer plans found in the TIP has been scaled based on the parameters which drive the number of equipment used in the terminals. The number of FDMA equipment found in the TIP applies to the number of users and aggregate data rate as described in the TIP for the given terminal. Since the aggregate data rate which must be supported by a terminal influences the number of modems employed, the scale factor used for the modems and associated equipment is the ratio of the total baseline terminal FDMA rate to the total FDMA rate of the terminal detailed in the TIP. Similarly, the number of user signals determines the number of multiplexers required. Therefore, the scale factor for multiplexers is the ratio of the baseline terminal FDMA users to the FDMA users of the terminal presented in the TIP.

Based on the multiplexer plans found in the TIP, representative multiplexer plans are constructed for each of the baseline terminals using the scaled numbers of equipment in the TIP for FDMA circuits, the Program Plan data for ECCM circuits, and the user signal information in Table 3-1. From these constructions the equipment-to-equipment connections and associated data rates are computed and presented in Tables C-1, C-2, and C-3 for the light, medium, and heavy baseline terminals, respectively. The LAN must provide a variety of services in terms of data rate and, as a result, the demand for each service must be assessed. The tables break up the number of connections, for each connection type, by data rate into representative services to show the number of connections requiring each service. For example, in the light terminal (Figure C-1), 3 connections require a service providing at least 64 Kbps.

The implementation of the full intercommunications LAN of Section 5 requires a Network Interface Unit (NIU) for each piece of equipment in the terminal. Since the complexity and cost of each of these NIU's depends on the number of connections to the LAN the associated equipment requires, a representative equipment listing including the number of connections to the LAN per device for the light, medium, and heavy baseline terminals is presented in Table C-4. End device in the terminal performs an operation

TABLE C-1
REPRESENTATIVE LIGHT TERMINAL CONNECTIVITIES

CONNECTION TYPE	NUMBER OF CONNECTIONS						
	1 Kbps	64 Kbps	500 Kbps	1 Mbps	2 Mbps	8 Mbps	TOTAL
FCC-98 / GSC-24 1 @ .825 Kbps 1 @ 15.15 Kbps	1	1					2
GSC-24 / R/T 1 @ 15.97 Kbps 1 @ 1050 Kbps		1		1			2
LRM / R/T 2 @ .75 Kbps 1 @ 64 Kbps	2	1					3
TOTAL	3	3		1			7

TABLE C-2
 REPRESENTATIVE MEDIUM TERMINAL CONNECTIVITIES AND RATES

CONNECTION TYPE	NUMBER OF CONNECTIONS						
	1 Kbps	64 Kbps	500 Kbps	1 Mbps	2 Mbps	8 Mbps	TOTAL
FCC-98 / GSC-24* 2 @ 1.8 Kbps 1 @ 5.85 Kbps 1 @ 52.8 Kbps 1 @ 350 Kbps 2 @ 128 Kbps 1 @ 832 Kbps 1 @ 1408 Kbps 2 @ 1544 Kbps		4	3	1	3		11
GSC-24 / R/T* 1 @ 1.8 Kbps 1 @ 7.65 Kbps 1 @ 180.8 Kbps 1 @ 1182 Kbps 1 @ 1536 Kbps 1 @ 3088 Kbps		2	1		2	1	6
LRM / R/T 1 @ 121.6 Kbps 1 @ 13.2 Kbps 1 @ 3.45 Kbps 1 @ .825 Kbps 5 @ .9 Kbps	6	2	1				9
KG-84 / LRM 2 @ 2.4 Kbps	2						
TOTAL	6	10	5	1	5	1	26

* NUMBER OF EQUIPMENT SCALED FROM NUMBER IN TIP.

TABLE C-3
REPRESENTATIVE HEAVY TERMINAL CONNECTIVITIES AND RATES

CONNECTION TYPE	NUMBER OF CONNECTIONS						
	1 Kbps	64 Kbps	500 Kbps	1 Mbps	2 Mbps	8 Mbps	TOTAL
FCC-98 / GSC-24 1 @ 1.5 Kbps 1 @ 1.725 Kbps 1 @ 1.8 Kbps 1 @ 24 Kbps 1 @ 51 Kbps 1 @ 88.8 Kbps 1 @ 401.6 Kbps 1 @ 808 Kbps 1 @ 960 Kbps 1 @ 1200 Kbps 4 @ 1544 Kbps		5	2	2	5		14
GSC-24 / R/T (MD-1007) 1 @ 1.725 Kbps 1 @ 344.8 Kbps 1 @ 307 Kbps 1 @ 280 Kbps 1 @ 769.5 Kbps 1 @ 1000 Kbps 1 @ 1704 Kbps 1 @ 1602 Kbps 1 @ 1538 Kbps 1 @ 3304 Kbps 1 @ 2888 Kbps		1	4	1	3	2	11
LRM/ R/T (USC-28) 1 @ .75 Kbps 1 @ 7.8 Kbps 1 @ 5.77 Kbps 1 @ 28.8 Kbps	1	3					4
KG-84/ R/T (USC-28) 5 @ 2.4 Kbps		5					5
TOTAL	1	14	6	3	8	2	31

TABLE C-4
REPRESENTATIVE EQUIPMENT LISTING

EQUIPMENT	NUMBER OF INPUTS FROM LAN*	NUMBER OF OUTPUTS TO LAN*	NUMBER REQUIRED		
			LIGHT	MEDIUM	HEAVY
ECCM R/T UNITS	1	1	4	14	31
MD-1002 R/T UNITS	1	1	4	9	33
KY-883	2	2	5	24	67
LRM	13	13	3	11	4
GSC-24	25	25	2	7	13
FCC-98	25	25	2	12	16

* NUMBER OF INPUTS/OUTPUTS GIVEN ARE WITH RESPECT TO THE LAN FOR EACH
PIECE OF EQUIPMENT.

in the user-to-RF direction of communication flow and the inverse operation in the RF-to-user direction. As a result, each input from the LAN to the equipment is accompanied by an output from the equipment to the LAN. For example, a multiplexer with 12 user inputs and one multiplexed output requires 13 inputs from the LAN (12 user inputs; 1 multiplexer input) and 13 outputs to the LAN (12 outputs to users; one multiplexer output). The data in Table C-4 accounts for the duplex nature of the inputs and outputs of equipment and accounts for redundant equipment.

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